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A Cinematographical Analysis of the Backward Roll to Handstand on the Parallel Bars

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A CINEMATOGRAPHICAL ANALYSIS OF THE BACKWARD ROLL TO HANDSTAND ON THE PARALLEL BARS

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THE PROBLEM

Introduction

The back roll to handstand is one of the smoothest and most precise movements on the parallel bars, when done with zest and speed. The flowing non-complicated appearance of the back roll to handstand has helped to account for its popularity, and skilled performance of this trick has been a valuable asset for parallel bar competitors. This is not to indicate, however, that the move is a simple skill on the parallel bars. The backward roll to handstand is given a high difficulty rating when the handstand is held.[1] The movement has appeared on a number of occasions in international set exercises. Those who have mastered the backward roll to handstand, including the Russians, and especially the Japanese, whose teams placed first and second in the 1956, 1960, and 1964 Olympic games, usually have used the movement in various combinations with other tricks, as an integral portion of their optional routines. Yukio Endo, gold medal winner on the parallel bars in the 1964 Olympic games, was one who used the backward roll to handstand from a peachbasket three-fourths

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[1]Amateur Athletic Union of United States, Official Gymnastics Rules (New York, 1962), p. 87.

layaway handstand.[2]

The backward roll to handstand has been commonly called a "strehle" in the United States. Other spellings of the same term for the backward roll to handstand have been streule, streille, straelie, and strueli. The pronunciation is the same although as indicated above, different sections of the United States spell the word differently.

The movement starts from the handstand position. The subject drops backward and downward to the upper arm support position; the legs are forced forward and the hips are flexed to a slight pike; then there is an extension upward and the arms push on the bars so the body shoots to a position above the bars. The arms were then thrust backwards over the head to regrasp the bars and quickly press the body to the stable handstand position.

Statement of the Problem

The problem was to analyze the backward roll to handstand on the parallel bars from cinematographical records to determine the essential mechanical principles which differentiate the more skilled from the lesser skilled, and thus to specify pertinent factors on which a skillful backward roll to handstand depended.

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[2]Glenn Sundly, "Endo's Olympic Parallel Bar Routine," The Modern Gymnast (March, 1965), VII, p. 20.

The cinematographical approach was chosen because fairly precise analysis of the external mechanics of many acts of skill may be made through use of this medium. Such factors as directions of movement (angles), dimensions, time relations, and indirect values of force and velocity may all be obtained from the film. Since the science of mechanics is an expression of physical laws of equilibrium or movement in terms of these same fundamental or derived measurements, a mechanical analysis of any movement may be made from measurements taken from the screen.[3] Cinematography was used to record these factors, since this process slowed down the entire movement to consecutive still positions which could be kept for unlimited study. The human eye cannot accurately concentrate on all the movements of the body parts as can the camera. The motion pictures provided a permanent sequence of still pictures for analysis. The purpose then was to provide a basis which would enhance learning and help reduce guessing and ambiguous hints as to the execution of the move.

Methodology

Motion pictures were taken of three gymnasts, after they had warmed up, as they performed the backward roll to handstand from four to five times. For purposes of

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[3]Thomas K. Cureton, Jr., "Elementary Principles and Techniques of Cinematographic Analysis as Aids in Athletic Research," Research Quarterly (May, 1939), X, p.5.

this study the three gymnasts were classified as subjects A, B, and C. A total of five performances were chosen for comparisons. Performance 1 being the most skilled and performance 5 being the least skilled. The five performances were specifically chosen to best show the complete sequence from the most skilled to the least skilled. The five backward rolls to handstand were ranked according to the height of the body achieved at regrasp, the time it took to press to the highest body position, and whether or not the handstand was held. The more closely the body approached the handstand position in the shortest amount of time from regrasp, the more skillful the performance. Performance 1 was the best execution of the skill done by Subject A. Performance 2 was also an execution of the stunt by Subject A. Performance 3 was the best execution of the skill by Subject B. Performance 4 was the best execution of the skill by Subject C. Performance 5 was a second though not as skillful a performance by Subject B.

The body outlines in the Appendix provided the basis for comparisons made between the 5 performances at ten selected positions during the backward roll to handstand. Two of the positions (release and regrasp) were superimposed and included to show the displacement and the direction of movement of the body and its parts. The

measurements in the seven Tables indicated various differences in performance which were indicative of differences in the skill of the performers.

Limitations

The backward roll to handstand was potentially dangerous to unexperienced gymnasts, so only gymnasts who could perform the stunt to some degree were used as subjects. A very limited number of subjects was available.

The backward roll to handstand was studied as a move in itself rather than as an intermediate part of a routine, in order to reduce the difficulty of controlling the correct positioning of the body and the timing on which skilled execution depended. The movement was started from the handstand position and was to end in the same position.

No synchronized clock of sufficient size was available to record time, so timing of the sequence of body positions was derived from the speed at which the pictures were taken. The exact starting or ending of a particular action may have occurred between two successive frames. That is to say, the hand may have been in contact with the bars in one frame and well off the bars in the succeeding frame. The exact instant of release or other selected positions may also have occurred between frames.

The locations of the center of gravity for the selected positions during execution were approximated due to the complex nature in determining this exact point for the continually changing body positions. Similarly, the center of the shoulder joint and hip joint were approximated. The elbow joint, wrist joint, knee joint, and ankle joint were found through placing a square piece of white tape on each joint before the pictures were taken.

Valid conclusions were possible to the extent that the comparisons between subjects were consistent with the differences in the skill exhibited.

CHAPTER II

REVIEW OF RELATED LITERATURE

In a study of the literature relating to the problem, it was found that very few studies had been made which duplicated the efforts of the writer. Of the studies found, only two included an analysis of the backward roll to handstand. The large majority of the studies done in the area of gymnastics deal exclusively with very fundamental movements.

Backward Roll to Handstand

The available literature which accurately described the execution of the backward roll to handstand was quite limited.

Yeager states that the strehle is merely a swing from a handstand position through an upper arm roll and back into the handstand.[4] If the backward roll to handstand is "merely" as Yeager describes, it would not be rated at a high difficulty by official gymnastics rules. Yeager describes the move in the following manner:

Order of Movement:

1. From the handstand, the shoulders are forced slightly backward from the hands. This permits the straight and arched body to swing backward,

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[4]Patrick Yeager, A Teacher's Guide for Men's Gymnastics (Georgia: Wide World Publications, 1963), p. 35.

downward, and forward in an upper arm swing position.

2. The straight body continues its swing forward and upward. This is executed on the upper arms as in the shoulder roll.

3. When the body reaches a point near the forty-five degree angle, the hands reach back over the head to grasp the bars.

4. The arms straighten, the back arches, and the performer assumes a handstand position.[5]

In studying Yeager's description of the movement, it would seem that there are several points that appear ambiguous in his wording or thinking. In the first step he refers to a "straight and arched body"--this cannot exist. Although he is undoubtedly trying to express his ideas so they can be understood easily, step one is confusing in the wording. A more accurate statement would have been that from the handstand position cast backwards to upper arms. In step two he finally states that this is being executed on the upper arms. An angle of forty-five degrees is prescribed before the hands reach backwards--forty-five degrees in relation to what, above the bars or horizontal to them? He did not mention anything about a piking and shooting action which gives the body the initial force to get off the bars.

If the movement was performed in the manner prescribed

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[5] Ibid.

by Yeager, the subject could undoubtedly end up in a straight arm support and not in the handstand position. It is evident that Yeager is approaching the subject as a layman, and transmitting what he has observed or heard in terms that a layman could understand. Approached in this manner, however, the true beauty and difficulty of the backward roll to handstand is not described.

Kunzle approaches the movement in more elaborate detail:

> Layout high from the handstand so that you really get a big swing. Hold your shoulders firmly in position with the elbows pressed down, grasping tightly with the hands. Also, keep the arms as straight as you can and press down strongly on them. This helps to accelerate the hips and legs upwards. Watch your toes until they rise above the bars. Hold the pike until the last movement, and then extend sharply. Hold the head back, hollow the back and shoulders, and press down as hard as you can with the elbows. As the shoulders come up off the bars, release your grasp and throw the arms backwards as fast as possible. Regrasp well behind the shoulders with arms bent and immediately press out to handstand. If you move the arms fast enough, you can regrasp as the shoulders are still rising, and continue the arm movement smoothly and without pause until you are in the handstand. The speed and confidence of this press out will make all the difference to the aesthetic appearance of the movement. From the movement you hollow out above the bars; you should be in a handstand like a flash.[6]

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[6]E.C. Kunzle, Parallel Bars (London: Barrie and Rockliff, 1964), P. 188.

A careful study of this second description would seem to indicate that Kunzel's analysis of the movement is more closely allied to that of this study. He indirectly describes the need of a controlled swing, and the necessity of the "piking and shooting" action, and the thrust through the arms to convert rotation energy into an upward thrust on the center of gravity.

Kunzle also stated that the timing of each part of the movement is critical if the performer is to be able to push through fast and confidently to a handstand. A little error either way and the performer would swing straight down or be forced to take several paces forward along the bars with the hands to correct the balance.[7]

Center of Gravity

Because of the center of gravity as an important factor in this study, it would be advisable for the reader to understand the term. Cureton stated that in vertical standing position the center of gravity is located approximately in the center of the waist on a level with the umbilicus.[8] However, lifting the arms overhead raises the center of gravity about two centimeters. A lift of the leg forward moves the center of

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[7] Ibid.

[8] Ibid., p. 21.

gravity forward and upward.

Since the human body during the execution of the backward roll to handstand was not a rigid body but a flexible, bending one, its separate parts did not maintain fixed distances from one another when subjected to the acting forces.

Hubbard stated that in a body with movable parts, such as the human body, the center of gravity moves with respect to a fixed point in the body as the parts change their relationship. The center of gravity is the point about which the separate masses times their distances sum to zero. Forces producing the translation, rotation, or projection of bodies can be treated as though they act on, or in relation to the center of gravity.[9] Therefore, the center of gravity, a point at which the whole weight of the body was concentrated, was used as a point of reference to facilitate analysis.

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[9]Alfred W. Hubbard, "Photography," Research Methods in Health, Physical Education, and Recreation (Washington D.C.: American Association of Health, Physical Education, and Recreation, 1959), p. 138.

CHAPTER III

METHOD OF RESEARCH

A number of gymnasts have gained proficiency in executing the backward roll to handstand through constant repetitive practice. The reduction of guess work from practice however, is basic to more efficient learning. Thus the learning process can be aided by mechanical explanations that help the learning of a stunt.

The purpose of the study was to analyze and compare the cinematographic record of individual performers in an effort to determine significant qualities contributing to skillfull execution. In order to specify which elements went into successful execution, critical distances (height of shoulder, ankle, and center of gravity) above the bars at "regrasp" and at "begin press" were studied. Angles of body parts, and duration of time between various phases of execution of the move for selected body positions were also measured.

Subjects

Performances 1 and 2 of Subject A were considered most skilled in the execution of the backward roll to handstand because the motion from "release" to handstand appeared continuous. Performance 1 of Subject A was

considered the most successful because he attained the most height upon "begin press" and because he held the handstand position. Performance 2 of Subject A pressed to the handstand in the fastest time, but did not hold the handstand position. Performance 3 of Subject B was considered a skilled performance in that he completed the backward roll to handstand. He attained the greatest height at regrasp, and also had the longest duration of time pressing up to the handstand position. Performance 4 of Subject C and Performance 5 of Subject B were least skilled because they failed to obtain the handstand positions. Subject C of Performance 4 regrasped the bars in a shoulder stand position and allowed his legs to fall as he pressed to a hand support. Subject B of Performance 5 was considered less skilled than Subject C Performance 4 because he rolled backward through the "begin press" position and then "pressed" when his legs were on the same level of the bars.

Recording Procedure

A 16 mm. Arriflex motion picture camera with the lens aperture ranging from F-1.8 to F-22 and Kodak 16mm. Tri-x film were used. The camera was electrically operated so the speed of the camera (50 frames per second) was held constant throughout the filming. This factor of consistency was used in determining the duration of

time between various phases of the movement.

The movements of the backward roll to handstand were almost entirely in the sagittal or anteroposterior plane around a transverse horizontal axis. The camera was placed 16 feet from the nearer bar, perpendicular to and approximately at the center of the movement so that direct angular and linear comparisons could be made.

For analysis, a Graflex, Galory Super 15 projector was used. The images were projected against a wall. The projector was situated in a position where the projected distance between two tape strips on the nearer bar was six inches between the inner edges. The actual distance between the inner edges of the two pieces of tape wrapped on the nearer bar was 6 feet. One inch was then equal to one foot. On the projected image, eight squares on the graph paper equaled one foot, or one square equaled one and one-half inches.

Analytical Procedure

Positions:

Since the subjects held the initial handstand for varying durations of time, the exact instant the movement started was difficult to determine. The "start" (position A) was the frame immediately before any noted movement occurred. Because of the difficulty in finding the exact frame when this occurred, the position "legs vertical"

was included because this position was standard for all subjects. The "shoulders touch" (position B) was taken as the frame immediately preceding the bending of the bars by the downward thrust of the body. This position was used to determine the initial difference from the center of gravity to hand grasp. "Legs vertical" (position C) was selected as the frame in which the body was most nearly vertical during the descent. This helped in the timing of various phases because the "leg vertical" position was standard for all subjects. The "deepest pike" (position D) indicated the smallest shoulder-hip-knee angle. The "begin shoot" (position E) indicated the start of hip extension by a definite increase in hip angle. The "release" (position F) was the first frame in which the hands appeared open. The "shoulders off" (position G) was the frame in which the shoulders were clearly off the bars. The regrasp (position H) was the first frame in which the parallel bars were caught. The "begin press" (position I) was the first frame in which the body started definitely upward to a handstand position. The "end press" (position J) was the first frame in which the arms of the subject appeared to be most straight and locked-out. In two cases (last two performances)the position of the body when the "end press" or when the arms appeared "locked" was not in a handstand, but in a hand

support position. Body outlines of these ten positions were traced on graph paper with the aid of a Graflex projector, which illustrated frame by frame movement, making possible comparisons between the subjects. (See Appendix)

In approximating the location of the center of gravity, a 360° transparent protractor was placed on the body image and was moved horizontally until half of the estimated weight times distance appeared to be on each side of the vertical axis. Then the protractor was moved vertically until half of the weight times distance appeared to be on each side of the horizontal axis. A mark was made at the point where both of the axes bisected each other. The protractor was then rotated and the apparent balance of the movements was checked on both axes as the protractor was moved through 90°.[10]

Angles:

Various angular measurements were used to indicate the positions of the various segments of the body in comparing the subjects at the ten different positions. The points on the body were the second finger of the right (nearer) hand for the grasp, the outer malleolus for the right ankle, the head of the ulna for the wrist, the center of the elbow, shoulder, and knee. On each of

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[10]Hubbard, Op. cit., p. 140.

these points a small, square piece of white tape was placed so as to illuminate and standardize these points in the analysis of the film. A point located near the head of the femur was approximated for the hips. The degree of pike or back arch was shown by the "hip" or shoulder-hip-knee angle, and the degree of bend in the elbow at "regrasp" and "begin press" was shown as the "arm" or grasp-elbow-shoulder angle. The remaining angles were measured from the vertical clockwise. Giving the apex first, the angles from the vertical to various segments of the body were center of gravity (shoulder to center of gravity), trunk (shoulder to hip), and body (shoulder to ankle).

CHAPTER IV

RESULTS

Five performances by three gymnasts were analyzed and compared by the use of cinematography to determine essential qualities contributing to skilled execution of the backward roll to handstand on the parallel bars. Performances 1, 2, and 3 were considered skilled because the Subjects obtained the greatest height at "regrasp" and "begin press." Performance 1 was rated most skilled because the subject continued with minimal delay from "regrasp" to "end press" and held a stable handstand. Performance 2 of Subject A had the shortest time from "regrasp" to "end press" but the subject failed to hold a stable handstand and had to move forward along the bars in order to retain his balance. Although Performance 3 showed the greatest height above the bars at regrasp, there was a much greater time lapse from "regrasp" to "end press." Performances 4 and 5 were considered least skilled because the handstand position was not reached. Performance 5 was considered less skilled than Performance 4 because at "end press" the body was in a lower position and showed no apparent slowing of the speed of rotation.

Aside from ending in a stable handstand position, "skill" was evidenced by the greater height of the shoulders, ankles, and center of gravity above the bars at "regrasp"

and "begin press"; by the tendency to continue ascent from the "regrasp" position to the "begin press" position; by the shorter elapsed time from "regrasp" to "end press" positions; and by keeping the lower limbs together and straight throughout execution.

Comparative Results

The body outlines in the Appendix represent the positions selected to show key differences in the execution of the backward roll to handstand.

Each of the five performances were started from a stably held handstand. The center of gravity for each subject at "start" was located on or near a line running through the hand, elbow, and knee indicating a balanced position. From this position the subjects dropped downward and backward to an upper arm support (position B). The center of gravity of Subject A's Performances 1 and 2 (at position B) was at a level equal to the height of the bars. The position of the center of gravity of Subject B--Performance 3 was located well above the bars, while the positions of the centers of gravity for Subject C--Performance 4 and Subject B--Performance 5 were well below the bars. The time lapse to travel from "start" to "shoulder touch" increased respectively from Performances 1 through 5.

Each of the subjects started a flexion of the hips (piking action) as their bodies had started to rise from

the "legs vertical position" until they reached the position of "deepest pike." This shortening of the body radius counteracted the decelerational effect of gravity during the ascent of the lower portion of the body. Subject A reached his "deepest pike" at nearly the same position in Performances 1 and 2, and had nearly equal angles of hip flexion. "Deepest pike" for Subject B--Performance 3 was attained at a position well below that obtained by Subject A's Performances; also, he did not attain as much of a flexion as did Subject A. Performance 4 showed the deepest or greatest hip flexion (pike) and also had the highest body angle. Performance 5 showed deepest hip flexion (pike) between the positions attained by Subject A.

The extension of the hips (begin shoot) was the main source of energy for converting the energy of rotation about the shoulders to an upward thrust on the center of gravity. As the legs were pulled forward into "deepest pike", there was a definite action against the firm fulcrum of the shoulders. The result was that the subjects' bodies were accelerated upwards. Each subject then extended the hips sharply. The exact timing of this extension was vital to skilled execution so as to insure that just enough force was applied in the right direction at the right time to stop rotation as the body approached the handstand position. The position of the center of gravity in Performances 1, 2, and 4, and 5 at begin shoot

was above the bar in each case, while Performance 3 had the center of gravity below the bar. The relative position of the hip at "begin shoot" for Performances 1 through 5, respectively, was just above, even with, well below, well above, and just below the bars.

The "begin shoot" and "release" positions in Performances 1 and 4 occurred in the same frame, indicating that the subjects extended their hips as they were releasing the bars. Performances 2, 3, and 5 showed that the subjects began their extension and then released the bars.

At "release" Performances 1, 2, and 4 showed a slightly flexed body position while Performances 3 and 5 showed straight body positions. Subject A's Performances 1 and 2 were still extending between the frames of "release" and "shoulder off." He was making further use of the bar to receive upward force. Subject B's Performances 3 and 5 had all his possible upward lift before reaching the shoulders off position. Subject C--Performance 4 was in a slightly flexed position at "shoulder off" also indicating that he did not extend upward forcibly but waited and extended backward.

At "regrasp" Performances 1, 2, and 3 showed the greatest shoulder height above the bar. At the same position, Performance 5 showed the greatest ankle height above the bar followed by Performances 4, 3, 1, and 2 respectively. It was apparent by the body outlines that the greater the ankle height above the bars at "regrasp" the nearer the subject

was to approaching a vertical position. The closer the subject was to the vertical position at "regrasp" the less his chances of obtaining the final handstand position due to the rotation of the body.

At "begin press" the subjects of Performances 1, 2, and 3 had continued their ascent before actually using their arm thrust. The position of the center of gravity at "begin press" for Performances 1 and 2 was well forward off a line passing vertically through the hands. The position of the center of gravity for Subjects B and C--Performances 3, 4, and 5 at "begin press" was directly over the hands. Subject A--Performances 1 and 2 was using his arm strength as a secondary force to push the center of gravity directly over the hands, while Subject B--Performance 3 had the center of gravity over his hands at "regrasp" and then used his arm strength as the major force to obtain the handstand.

At "end press" Subject A--Performance 1 had attained a handstand position with the center of gravity over the hands. In his second performance Subject A had to move forward on his hands in order to have the center of gravity above them to assume a stable handstand position. At "end press" Subject A--Performance 2 was in an overbalanced position. Subject B--Performance 3 attained a handstand by pressing straight upward from his "begin press" position. Subject C--Performance 4 at "end press" was in a position with the center of gravity over and above his hands, but

his body was nearly horizontal to the bars. Subject C--Performance 5 had the center of gravity over and above his hands and his body was well below the horizontal in a front support position.

Factual Results

The data in Table I showed that the distance the hands traveled laterally along the bars from release to regrasp in Performances 1 through 5 was 21, 21.75, 24.75, 30.0, and 29.25 inches respectively. The shorter the distance of the reach the more vertical the arm thrust. As the distance lengthened, more horizontal pull was necessary to get the center of gravity over the hands. At regrasp the position of the shoulder in relation to the hand was directly above for Performance 1, while the shoulder was progressively more in front of the hand from Performances 2 through 5.

TABLE 1

DISTANCE IN INCHES ALONG BAR OF GRASP FROM RELEASE TO REGRASP

Performance	Inches
1	21
2	21.75
3	24.75
4	30
5	29.25

In Table 2, the hip angle at deepest pike in the five performances was 117, 118, 128, 103, and 122 degrees. Performance 4 had the greatest hip flexion while Performance 3

had the least. The greater hip flexion did not indicate the more skilled over-all performance as shown.

The arm angles (grasp-elbow-shoulder) of the Performances 1 through 5 at regrasp and begin press were 34 and 49 degrees, 40 and 64 degrees, 44 and 57 degrees, 52 and 50 degrees, and 43 and 43 degrees. Performance 2 had a positive change from regrasp to begin press of 24 degrees, which showed the continued ascent of the body. Performance 1 had a positive change of 15 degrees, and Performance 3 had a positive change of 13 degrees. Performance 4, on the other hand, decreased 2 degrees, and Performance 5 remained the same. Performance 4 and Performance 5 did not have the continuous ascent from grasp to begin press.

TABLE 2

ANGLE OF BODY PARTS
WITHIN THE BODY

Body Parts	Degrees of Performances 1	2	3	4	5
Hip (between adjacent segments)					
Deepest pike	117	118	128	103	122
Begin shoot	124	124	134	106	125
Release	124	146	170	106	155
Regrasp	202	205	210	176	215
Begin press	218	226	201	199	209
Arm (grasp-elbow-shoulder)					
Regrasp	34	40	44	52	43
Begin press	49	64	57	50	43

In Table 3 the angle of the trunk (shoulder-hip line) at deepest pike for the three subjects shows 100, 102, 126, 96, and 118 degrees respectively. Subject A--Performances 1 and 2 reached his deepest pike when the trunk was approaching the horizontal. Subject B--Performances 3 and 5 was well below the horizontal when he attained deepest pike. The trunk of Subject C--Performance 4 was at the horizontal at deepest pike. The angle of the shoulder center of gravity line for the five performances was 85, 87, 110, 79, and 92 degrees respectively. The center of gravity of Performances 1 and 2 were just above the horizontal (bar). The center of gravity for Performances 3 and 5 were below the horizontal, while the center of gravity of Performance 4 was well above the horizontal. This shortening of the body radius counteracted the deceleration effect of gravity during the ascent, and offered the body upward momentum.

The angle of the trunk (shoulder-hip line) at begin shoot for the subjects of the five performances was 85, 93, 109, 76, and 100 degrees respectively. Subject A--Performances 1 and 2 began his extension when he was at the horizontal. Subject B--Performances 3 and 5 began his extension before he reached the horizontal. Subject C--Performance 4 began his extension above the horizontal.

The body angle (shoulder-ankle line measured from the vertical clockwise) of each performance at release was 68, 70,73, 55, and 59 degrees respectively. The body angle at

shoulders off (frame when shoulders were clearly off the bars) for the executions was 55, 59, 69, 36, and 42 degrees. From the time of release to the time that the shoulders were clearly off the bars the subjects rotated through 13, 11, 13, 19, and 17 degrees respectively. The more skilled exhibited less rotation indicating more thrust upward by hip extension. The angle of the body at regrasp for the five performances of the three subjects was 49, 55, 37, 31, and 30 degrees respectively. The body angle in each case at begin press was 43, 51, 342, 355, and 349 degrees. The angles attained by Subjects B and C--Performances 3, 4, and 5 had passed beyond the vertical as indicated by the three digit number. The total degree of body rotation for the subjects from release to begin press was 25, 19, 91, 60, and 70 degrees respectively. Subject A--Performances 1 and 2 had the least number of degrees in body rotation indicating success in upward thrust. Subject B--Performance 3 had the largest body rotation but succeeded in stopping the rotation and pressed to the handstand. Subjects B and C--Performances 4 and 5 did not stop the rotation force and thus did not finish in a handstand position.

The angle of departure of the center of gravity measured from release to regrasp was 332, 334, 329, 308, and 307 degrees respectively for the five performances. Subject A--Performances 1 and 2, and Subject B--Performance 3 showed greater upward angle than Subject C--Performance 4,

and Subject B--Performance 5 who were definitely in a more horizontal position to the bars. The more skilled were thrusting their centers of gravity upward to stop the rotation about the shoulders. Subject C--Performance 4 and Subject B--Performance 5 shortened the radius of rotation by piking as did Subject A--Performances 1 and 2, and Subject B--Performance 3; but they waited and extended too late for any effectiveness against over-turning.

TABLE 3

ANGLE OF BODY PARTS MEASURED FROM THE VERTICAL CLOCKWISE

Position	Degrees of Performances				
	1	2	3	4	5
Deepest pike					
Trunk (apex at shoulder)	100	102	126	96	118
Center of Gravity (apex at shoulder)	85	87	110	79	92
Begin shoot					
Trunk (apex at shoulder)	85	93	109	76	100
Center of Gravity (apex at shoulder)	75	81	96	55	85
Body angle (shoulder-ankle line)					
Release	68	70	73	55	59
Shoulders off	55	59	60	36	42
Regrasp	49	55	37	31	30
Begin press	43	51	342	355	344
Angle of departure of center of gravity at release	332	334	329	308	307

Table 4 shows the velocity of the centers of gravity (feet per second) between release and regrasp. The distance in feet was recorded in Table 4, and the time in seconds was shown in Table 7.

TABLE 4

DISPLACEMENT IN INCHES OF CENTER OF GRAVITY FROM RELEASE TO REGRASP

Position	Inches of Performances				
	1	2	3	4	5
Vertical	12.75	12.0	14.25	12.75	11.25
Horizontal	6.75	6.0	7.50	10.50	16.50

The velocity (feet per second) of the center of gravity at release helped to indicate the degree of effective and ineffective motions for lift. The performances of the three subjects had respective vertical and horizontal velocities of 6.64 and 3.52; 7.14 and 3.57; 4.57 and 2.40; 5.31 and 4.38; and 3.91 and 5.73 feet per second. The difference of the vertical and horizontal velocities gave an indication of the power of the vertical or upward thrust. Subject A--Performance 2 had the greatest differences of 3.57 feet per second. Subject A--Performance 1 followed with 3.12, then Subject B--Performance 3 with 2.17, and Subject C--Performance 4 with .93. Subject B--Performance 5 had -1.82 feet per second indicating that he had 1.82 feet per second more horizontal velocity than vertical velocity. The greater the vertical

velocity, the better the chance of reaching the hand stand position.

TABLE 5

VELOCITY (FEET PER SECOND) OF CENTER OF GRAVITY AT RELEASE

Position	Feet p/s of Performance 1	2	3	4	5
Vertical	6.64	7.14	4.57	5.31	3.91
Horizontal	3.52	3.57	2.40	4.38	5.73

The height of the center of gravity as shown in Table 6 at regrasp and begin press showed the tendency of continual ascent between these two positions. The five performances of the three subjects at regrasp had center of gravity at the following heights: 17.25, 18.0, 18.75, 16.5, and 18.75 inches respectively, while at begin press the subjects had a center of gravity height of 21.0, 20.0, 20.25, 16.5, and 16.5 inches respectively. The center of gravity of Subject A--Performance 1 continued ascent between regrasp and begin press 3.75 inches while the center of gravity of Subject A--Performance 2 continued ascent 2 inches, and the center of gravity of Subject B--Performance 3 continued upward 1.5 inches. Subject C--Performance 4 remained at the same height for both positions. Subject B--Performance 5 lost 2.25 inches between regrasp and begin press.

TABLE 6

HEIGHT IN INCHES ABOVE THE BAR

Position	Performances 1	2	3	4	5
	Inches				
At Center of Gravity					
Regrasp	17.25	18.00	18.75	16.50	18.75
Begin press	21.00	20.00	20.25	16.50	16.50
At Regrasp					
Shoulder height	3.75	3.75	4.50	2.25	2.25
Ankle height	33.75	30.00	42.25	42.25	43.50
At Begin Press					
Shoulder height	6.75	5.25	6.75	3.00	3.75
Ankle height	38.25	32.25	51.75	47.25	49.50

The height of the shoulders and ankles at regrasp for the subjects were 3.75 and 33.75; 3.75 and 30.0; 4.5 and 42.25; 2.25 and 42.45; and 2.25 and 43.5 inches. The height of the shoulders and ankles at begin press were 6.75 and 38.25; 5.25 and 32.25; 6.75 and 51.75; 3.0 and 47.25; and 3.75 and 49.5 inches respectively. Each of the subjects had a definite increase in shoulder height above the bars between the frames of regrasp and begin press. Subject A--Performance 1 had a 3.0 inch increase; Subject A--Performance 2 had a 1.5 inch increase; Subject B--Performance 3 had a 2.25 inch increase; Subject C--Performance 4 had a .75 inch increase; and Subject B--Performance 5 had a 1.50 inch increase in shoulder height. The ankle height between regrasp and begin press increased for the performances of the subjects 4.5, 2.25, 4.5, 5.0,

and 6.0 inches respectively. A comparison of the differences in shoulder and ankle height showed that the ankle height was increasing at a much faster rate than was the shoulder height. This increase is most substantial in the heights produced by Subject C--Performance 4 and Subject B--Performance 5. The position of the Subject's ankles in relation to a vertical line passing through the hand of the begin press position was well forward of the line for Subject A--Performances 1 and 2, while Subject B--Performance 3's ankles were behind the line, and Subject C--Performance 4 and Subject B--Performance 5 had their ankles on the line. Performers 4 and 5 never obtained the handstand position, but passed through this vertical position. Subject B--Performance 3 was able to press up to the handstand after he had positioned the center of gravity directly above the base of support. Subject A--Performances 1 and 2 pushed up quickly to the handstand, moving his center of gravity to a position above the base of support at end press, not before. He ended in a position of high potential energy. Subject B--Performance 3 reached his highest potential energy at begin press, while the performances of Subjects 4 and 5 showed that they never reached high potential energy.

Table 7 shows the elapsed time from start to legs vertical which helps to indicate the speed of drop,

thereby estimating the amount of energy. The time required to reach legs vertical for five performances was 1.28, 1.20, 1.46, 1.36, and 1.46 seconds respectively. Subject A--Performances 1 and 2 took less time, thus more speed gave him more energy during descent than the other subject's performances.

TABLE 7

ELAPSED TIME (SECONDS) BETWEEN PHASES

Phases	Seconds of Subjects 1	2	3	4	5
Start to shoulder touch	1.04	1.00	1.16	1.16	1.20
Shoulder touch to legs vertical	.24	.20	.30	.20	.20
Legs vertical to deepest pike	.26	.24	.20	.10	.26
Deepest pike to begin shoot	.04	.02	.04	.06	.02
Begin shoot to release	.00	.04	.06	.00	.06
Release to shoulders off	.08	.08	.12	.12	.14
Shoulders off to regrasp	.08	.06	.14	.08	.10
Release to regrasp	.16	.14	.26	.20	.24
Regrasp to begin press	.06	.04	1.00	.32	.24
Begin press to end press	.50	.40	1.00	-	-
Regrasp to end press	.56	.44	2.00	-	-
Start to end press	2.30	2.08	4.02	-	-

The time elapsed between legs vertical and deepest pike indicated the speed with which each subject attained their greatest flexion of the hips. The performances showed times of .26, .24, .20, .10, and .26 seconds respectively between the positions of legs vertical and deepest pike. Subject C--Performance 4 had a time lapse of .10 seconds between legs vertical and deepest pike. He also had the greatest hip flexion at deepest pike. This indicated that he started piking sooner than the

other subjects, thus shortening the body radius and increasing the speed of rotation. Subject B--Performance 3 had an elapsed time of .20 seconds between legs vertical and deepest pike, but this was due to the fact that he reached deepest pike when his hips were well below the bars, whole the other subjects' hips were above the bars.

The elapsed time between begin shoot to release indicated the speed of hip extension. The elapsed time for the performances was .08, .12, .18, .12, and .20 seconds respectively. The more vigorous the extension, the more effective would be the lift, if the extension was in the proper direction. The time of hip extension for Subject A--Performances 1 and 2, and Subject B--Performances 3 and 5 correlated with the degree of skill for each. Subject C--Performance 4 had waited (refer to "begin shoot" in Appendix) too long before he began his extension, the result being that the hip extension was not in the proper direction, but backwards, and he did not receive any appreciable lift.

The time interval between release and regrasp indicated the speed with which the performer ascended to a position from which he could press to the handstand. The quicker the bars were regrasped the greater the chance of ascending continuously to the handstand. Subject A--Performance 2 had the shortest time interval between release and regrasp of .14 seconds. Subject A--Performance 1 followed

with a time of .16 seconds, and Subject B--Performance 3, Subject C--Performance 4, and Subject C--Performance 5 had respective times of .26, .20, and .24 seconds.

The time elapsed between regrasp and begin press helped to indicate the speed with which the performers continued their ascent. The time for the performances of the subjects was .06, .04, 1.0, .32, and .24 seconds respectively. Subject A--Performances 1 and 2 upon regrasp almost immediately began to press upward to the handstand. Subject B--Performance 3 waited 1.0 seconds before he began his press. Subject C--Performance 5 waited .32 seconds and Subject B--Performance 5 waited .24 seconds before they made an appreciable effort to straighten their arms.

The shorter the time interval between begin press and end press the faster would be the press and the handstand. Subject A--Performances 1 and 2 took .50 and .40 seconds indicating that he did not hesitate in his upward press. Subject B--Performance 3 took one full second to complete his press to the handstand position, indicating that he had spent time in obtaining a stable position from which he could press upward. Subject C--Performance 4 and Subject B--Performance 5 did not complete the trick to the handstand position so their times to end press are meaningless.

Minimizing the interval between regrasp and end

press indicated control in completing the trick, and avoided the appearance of the break in continuity. Subject A--Performances 1 and 2, and Subject B--Performance 3 completed the trick in .56, .44, and 2.0 seconds respectively. Subject A's performances had the shortest time in completing the trick and had a smoothly flowing finish. Subject B--Performance 3, on the other hand, took 2 seconds from regrasp to end press, which caused a break in continuity and gave the trick a choppy appearance.

Summary of Results

The basic mechanical problems in the execution of the backward roll to handstand were (1) developing maximum force during the descent with control, (2) shortening the body radius by piking to conserve momentum for the ascent and to obtain a position from which the subjects could "shoot," (3) extending the hips for the initial lift in the proper direction and at the proper time, (4) regrasping the bars quickly with residual ascending force and minimal lateral force, and (5) applying arm force quickly upon regrasp to give smooth, non-hesitant appearance.

Each of the subjects started from a stable handstand and then dropped downward and backward to upper arms. The more skilled performer (Subject A--Performances 1 and 2) reached "legs vertical" in a shorter lapsed time from the starting position. Since he traveled essentially

the same distance in a shorter time in each case, he created more downward force. Subject B--Performances 3 and 5, and Subject C--Performance 4 (the lesser skilled) took a longer period of time to reach "legs vertical" whereby they had controlled their descent to a greater degree and also lessened the downward force.

All of the subjects flexed their hips after passing through the "legs vertical" position until they reached "deepest pike" the frame where they attained maximum flexion. The shortening of the body radius (piking) served to conserve momentum, to increase rotating velocity, and to position the body for the extension or "shoot." The more skilled subjects reached "deepest pike" when their hips were level to the bar, giving greater potential for the upward thrust. The lesser skilled performers reached "deepest pike" when their hips were above (Subject C--Performance 4) or below (Subject B--Performances 3 and 5) the level of the bar. Subject A--Performances 1 and 2 had greater hip flexion than did the lesser skilled Subjects B and C. Subject C--Performance 4 had the greatest hip flexion which in his case caused overturning. Subject C--Performance 4 reached deepest pike in the shortest elapsed time with the greatest amount of hip flexion which caused him to have residual rotation from which he did not extend fast enough to convert this force into an upward

lift. The more skilled subjects attained the necessary amount of hip flexion necessary to conserve momentum during the ascent and to place them in a position where they could better "extend" to stop the rotation and receive upward lift.

The more skilled subjects began their extension when their hips were in a position just above the level of the bars. Subject B--Performances 3 and 5 began his extension when his hips were in a position well below the level of the bars. Subject C--Performance 4 began his hip extension when his hips were well above the level of the bars. Extending "too early" checked the rotation of the body but did not afford it any upward lift. Extending "too late" caused a backward rolling action, no lift. The more skilled were completely extended in a shorter elapsed time indicating that they had a more vigorous extension.

At the moment of release Subject A--Performances 1 and 2, and Subject B--Performance 3 had angles of departure of 332, 334, and 329 degrees respectively at the point of regrasp, while the lesser skilled subjects had angles of departure of 308 and 307 degrees. The greater angle degree for the more skilled subjects indicated that they extended upward at an angle close to the vertical, thus receiving lifting force.

The body angles (shoulder-ankle line) for the more

skilled subjects at release were 68, 70, and 73 degrees respectively, while the body angles for the least skilled were 55 and 59 degrees. Subject C--Performance 4 and Subject B--Performance 5 waited too long before they extended and released the bars.

The difference between the vertical and horizontal velocities at release for the subjects was 3.12, 3.57, 2.17, .93, and -1.82 feet per second. These numbers indicated the amount of vertical velocity over the horizontal velocity. Subject A--Performances 1 and 2, and Subject B--Performance 3 had the greatest amount of vertical lifting force while Subject B--Performance 5 had the greatest horizontal force; he also had 1.82 times as much horizontal force as vertical force. It was evident from the amount of vertical and horizontal velocities for Subject A--Performances 1 and 2 that he made the most of his extension.

The distance along the bar that the hands of the more skilled moved from "release" to "regrasp" was 21, 21.75, and 24.75 inches, while the distance between the hands of the lesser skilled from "release" to "regrasp" was 30 and 29.25 inches. The more skilled had shorter durations in time between "release" and "regrasp" because of the shorter distance traveled. The faster the regrasp the more continuous was the ascent of the body because the arm force was added to the upward thrust

of the hip extension.

At "regrasp" the more skilled had greater body height than did the less skilled. The more skilled made better use of their direction and timing of hip extension than did the lesser skilled.

The more skilled also had greater gains in body height from "regrasp" to "begin press" than did the lesser skilled. Subject A--Performances 1 and 2, and Subject B--Performance 3 continued to ascend before beginning to use arm force. This gave the movement a smoother appearance. The angle of the arm between "regrasp" and "begin press" for the more skilled increased as did their body height. The arm angle of the lesser skilled between "regrasp" and "begin press" decreased or stayed the same, due to lack of vertical lift.

The time lapse between positions "regrasp" and "end press" indicated the effectiveness of the vertical lifting force of the hip extension and the arm force. The more skilled, Subject A--Performances 1 and 2, had times of .56 and .44 seconds. Subject B--Performance 3 had a time of 2 seconds from regrasp to end press. Subject A--Performances 1 and 2 made more effective use of his "shoot," direction of shoot, and arm force than did Subject B--Performance 3. Subject C--Performance 4 and Subject B--Performance 5 did not complete the movement

to the handstand position due to failure in one of the basic mechanical problems involved in executing the backward roll to handstand.

Summary of Performances

As can be seen from the factual analysis and from a study of the body outlines in the Appendix, the performances varied in degree of excellence and accuracy of execution. An analysis of each performance would seem to indicate the following: Subject A--Performances 1 and 2 had the shortest time from start to shoulder touch, indicating that he had attained greater speed to help in the ascent of the body. He attained a deep pike and then extended in the most optimum direction. He also had the shortest distance of movement along the bars from release to regrasp, and had the shortest elapsed time from regrasp to end press. The significant difference in the two performances was that in Performance 2 the subject began his extension a little too soon, which caused him to walk forward on his hands to bring his center of gravity within the base of his hands to retain his balance. Aside from this important factor the two performances were nearly identical. Timing of the extension was a vital factor in skilled performance of the movement.

Subject B--Performance 3 took a longer time than Subject A in reaching the shoulder touch position, thereby

not gaining as much momentum. Subject B in Performance 3 did not attain as deep a pike as did Subject A, and began his extension much earlier than Subject A. He did, however, roll back on his shoulders before actually releasing a longer time, which enabled him to assume a more vertical position upon regrasp, preventing him from over-balancing. He had the longer time interval from release to regrasp, signifying that he "floated" too long and had a very slow arm movement. The distance of travel along the bar was also greater than in the performance of Subject A. Subject B in Performance 3 upon regrasp hesitated and waited for the center of gravity to travel over the base of support which gave an appearance of a break in the movement. His major errors in the execution of the skill were (1) not obtaining enough hip flexion, (2) extending too early, (3) reaching too far back along the bar, and (4) pausing too long before pressing to the end press position. The errors however, were so slight that he was still able to complete the movement with some success.

Subject C--Performance 4's major fault was that he did not extend forcibly enough and at the right time and in the correct direction to get the initial lift off the bars. He attained the deepest pike but did not make use of it. The subject attained his deepest pike well above the other subjects and began his extension much later.

He extended more backwards than in an upward direction which did not give him much lift off the bars. He received a turn-over action because he did not check his speed of rotation soon enough. Reaching back the greatest distance along the bar made him pull his body back towards his hands instead of pushing his body upward. This factor then caused him to end up in a high support position rather than in a handstand.

Subject B in Performance 5 had the following faults in his execution of the skill: (1) he did not attain enough flexion of the hips, (2) he began his extension too early, (3) his extension was in too horizontal a direction, not giving him sufficient lifting power, (4) he spent too much time from release to regrasp causing his body not to have a continuous ascent, (5) he was not fast enough with his arm movement from release to regrasp, (6) he reached too far back along the bars, and (7) instead of pressing upward upon regrasp, he waited until his center of gravity came within the base of support; however, by then it was too late to stop the speed he had accumulated from rotation. When he did press upwards with his arms, he was already in a front support position rather than in the handstand position.

CHAPTER V

CONCLUSIONS

The problem was to analyze the backward roll to handstand on the parallel bars from cinematographical records to determine the essential mechanical principles which differentiated the more skilled from the lesser skilled, and consequently to specify pertinent factors on which a skillful backward roll to handstand depended.

Sixteen millimeter motion pictures were taken of three gymnasts performing the backward roll to handstand from four to five times each. For purposes of this study the three gymnasts were classified as subjects A, B, and C. A total of five performances were chosen for comparisons. Performance 1 being the most skilled and performance 5 being the least skilled. The five performances were specifically chosen to best show the complete sequence from the most skilled to the least skilled. The five backward rolls to handstand were ranked according to the height of the body achieved at regrasp, the time it took to press to the highest body position, and whether or not the handstand was held. The more closely the body approached the handstand position, in the shortest amount of time from regrasp, the more skillful the performance. Performance 1 was the best execution of the skill done by Subject A.

Performance 2 was also an execution of the stunt by Subject A. Performance 3 was the best execution of the skill by Subject B. Performance 4 was the best execution of the skill by Subject C. Performance 5 was a second though not as skillful a performance by Subject B.

With the use of a Graflex projector the body outlines for ten selected positions were traced onto graph paper with a scale of one inch equaling one foot. The body outlines provided the basis for the comparisons made. The data of the Tables reflects the various differences in performance which were indicative of differences in the skill of the performer.

Summary of Findings

The subjects started from a stable handstand position. They then casted backward and downward under control to an upper arm supporting position. The more skilled subjects took a shorter lapsed time to descend, which indicated that they had more downward force.

The more skilled subjects began piking to shorten the radius of the body, which increased rotating velocity and placed them in a position from which to shoot to the handstand position. The more skilled subjects attained the amount of hip flexion necessary for them to attain maximum lift upon extension. The more skilled subjects began their extension when their hips were in a position just above the bars. At the moment of release the more

skilled were shooting more directly upward then were the lesser skilled, and the time lapsed for the extension of the more skilled was shorter, indicating that they had a much more vigorous extension. The position and timing for "deepest pike" and "begin shoot" were essential parts of skillful execution. These two positions were the most important phase of the movement.

The more skilled subjects upon "regrasp" reached closer to the "release" position than did the lesser skilled. The more skilled had shorter durations in time between "release" and "regrasp," because of the shorter distance travelled. The faster the regrasp the more continuous the ascent of the body, because the arms were adding to the upward thrust of the hip extension. The time elapsed between "release" and "regrasp" was much shorter for the skilled subjects than the lesser skilled. This elapsed time indicated the effectiveness of the hip extension and the arm thrust in attaining the handstand.

Conclusions

The following essential factors arranged in order of execution were gathered from preceding conclusions in order to provide a guide to facilitate the learning of the backward roll to handstand.

1. From a stable handstand position cast backward and downward at full extension to an upper arm supporting position, with maximum force during the descent with control.

2. As the body begins to ascend, start a flexion of the hips. The degree of flexion depends on the gymnast and his abilities; however, intent of the movement is to place body in a position for upward thrust.

3. From the piked position extend forcibly in a vertical direction. The exact position and the direction of the shoot will depend on the gymnast's ability. Optimum timing and direction of shoot are essential in lifting the body from the bars.

4. Throw the arms backward quickly, regrasping as close to the previous position as is possible. The regrasp should occur as the body is still rising, thus eliminating the necessity of overcoming the force of gravity while hands are being placed on the bar.

5. With a continuous motion apply arm force smoothly and without hesitation to the handstand position.

Poor performance may be due to one or more of the following faults:

1. No hip extension: the body will not lift off the bars and the handstand position cannot be reached.

2. Extending too early: the necessary height cannot be reached usually causing finish in a bent arm balance position.

3. Extending too late or not sharply enough: thus causing an over-rotation and a finish in front support position.

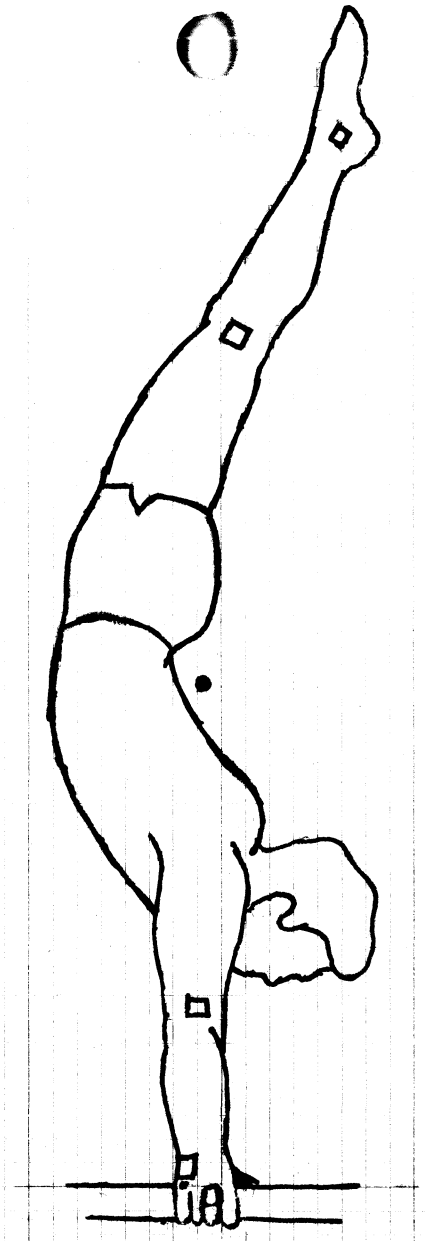
4. Slow arm movement at regrasp: pressing too late and achieving only a high support position.

The writer recognizes that the study was based on a limited number of subjects. Because individuals

differ in body size and proportions, it is possible that slight variations in execution might occur, even in so-called "skilled" performances. However, the basic principles which must be adhered to for correct execution should remain constant from one performance to another.

It is recommended that further study involving a greater number of performances be made to determine the extent to which individual differences might affect the execution of the skill when done in an acceptable manner.

APPENDIX



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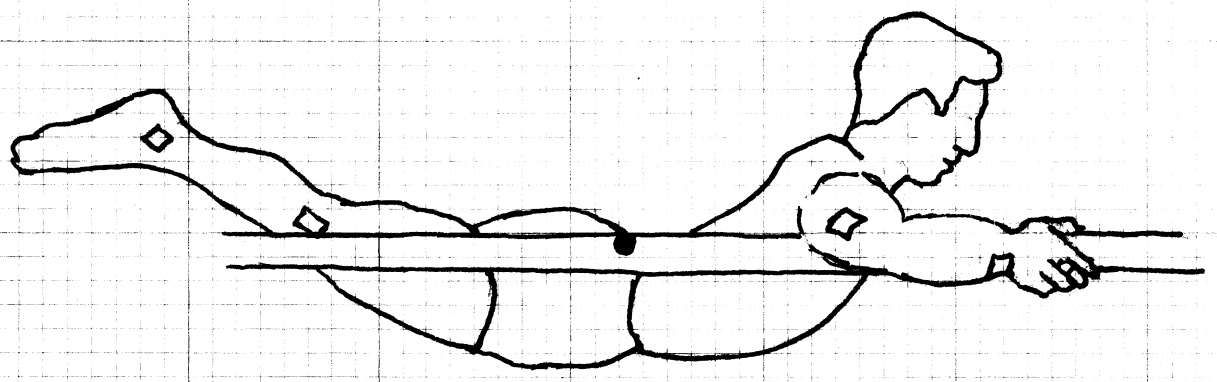
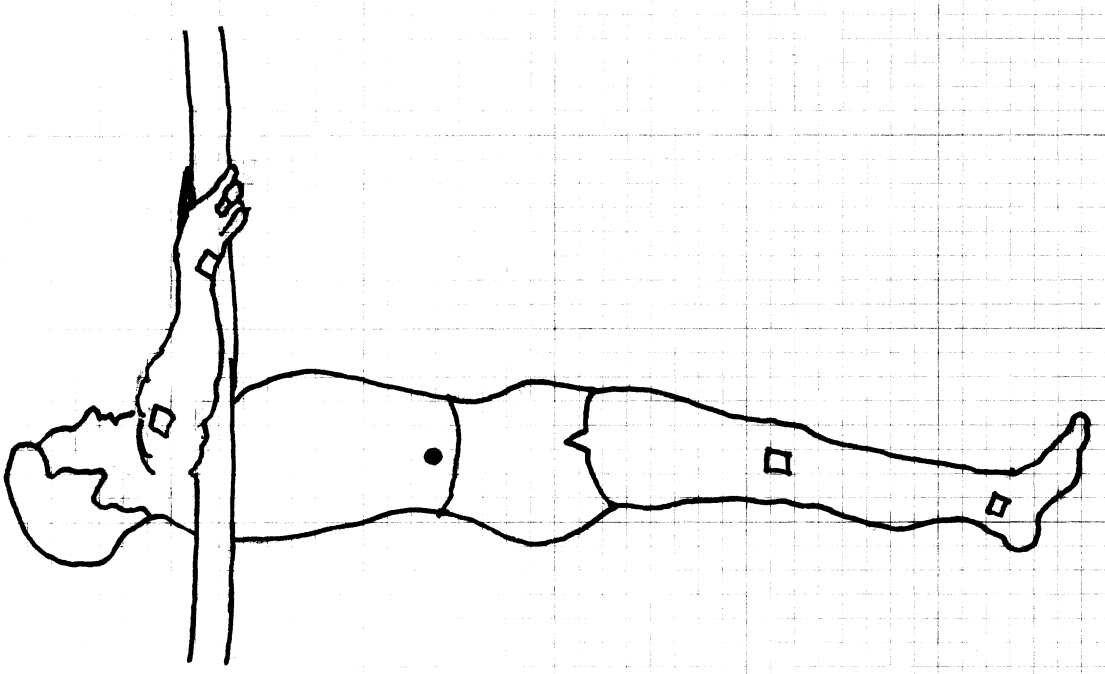


PERFORMANCE 1
SUBJECT A
SHOULDER TOUCH
FRAME 53

PERFORMANCE 1
SUBJECT A
LEGS VERTICAL
FRAME 65



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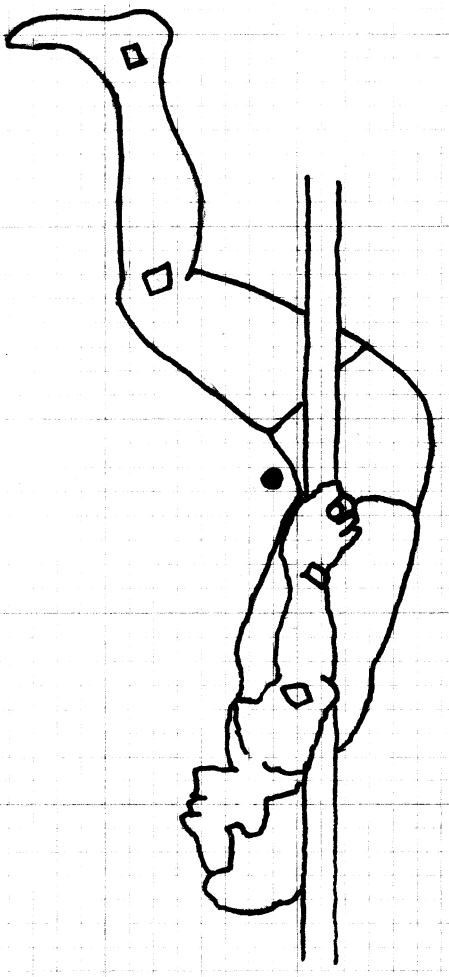
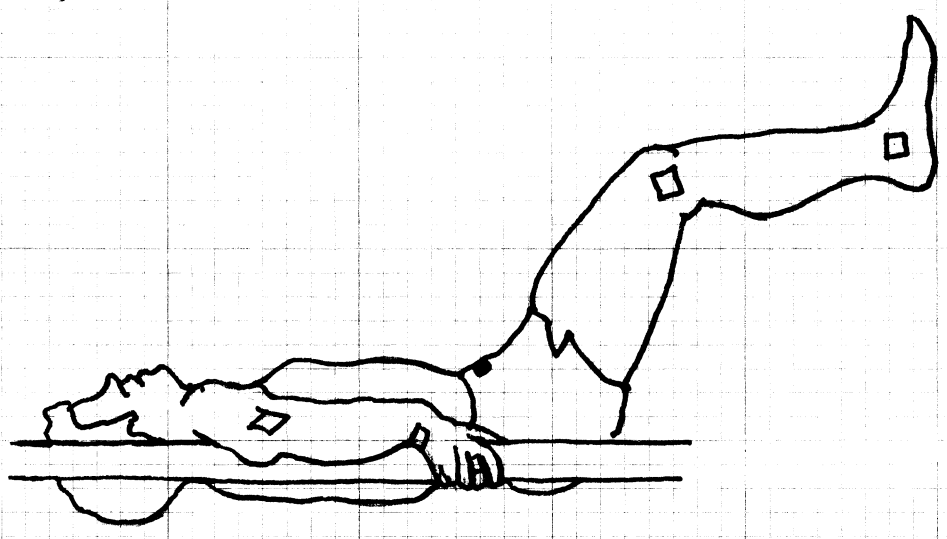
DEEPEST PIKE
FRAME 78





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BEGIN SHOOT
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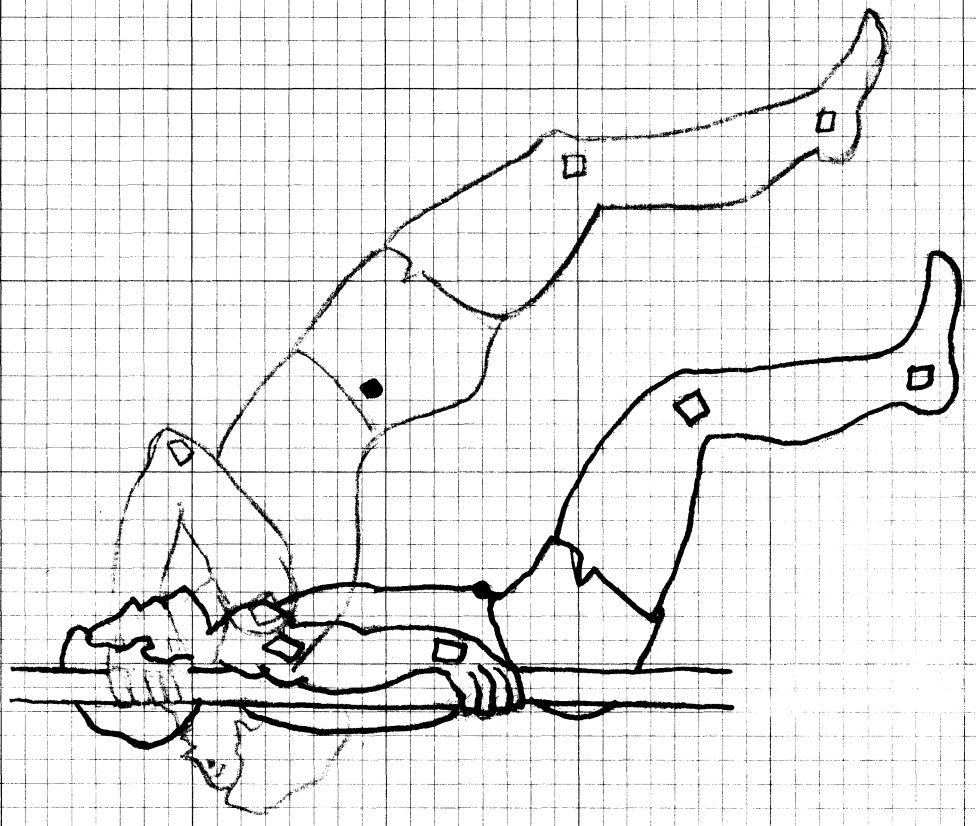


PERFORMANCE 1

SUBJECT A

REGRASP

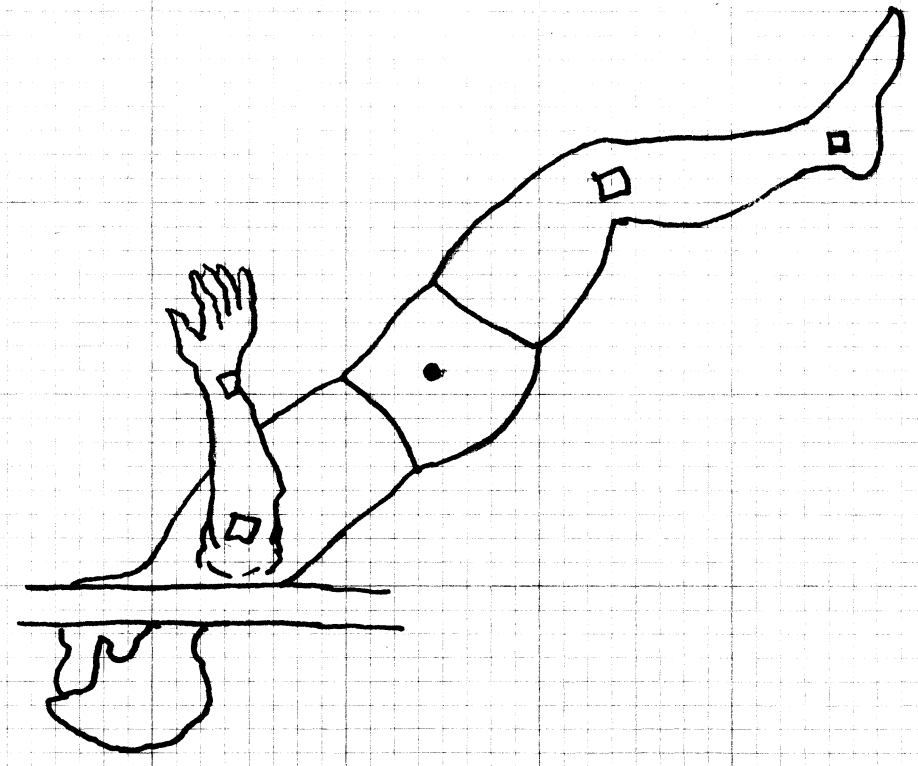
FRAME 88

PERFORMANCE 1

SUBJECT A

RELEASE

FRAME 80



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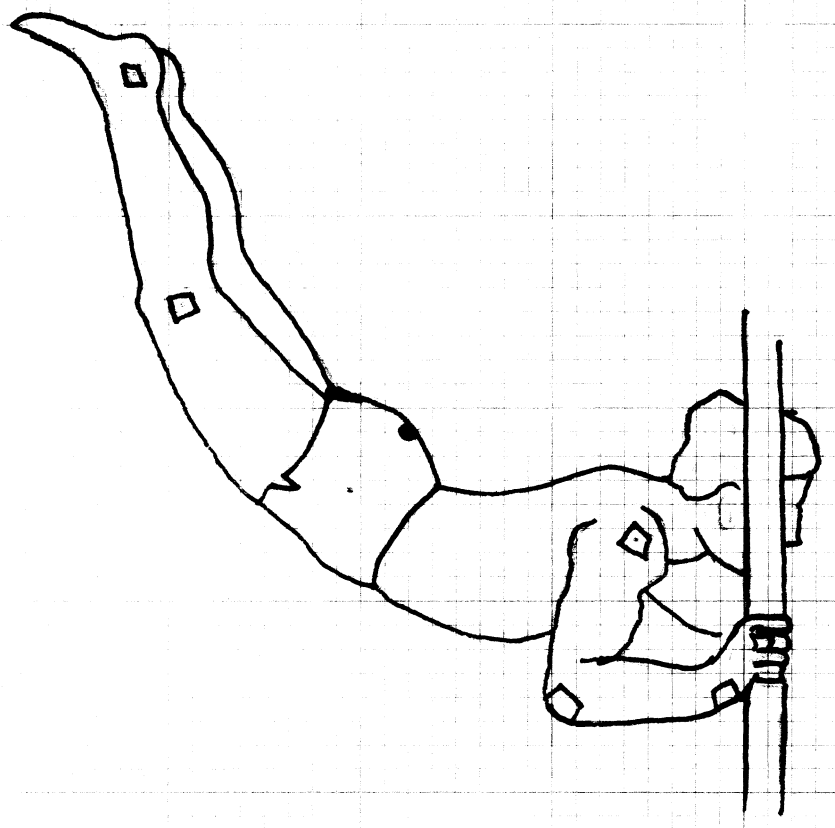
SUBJECT A
SHOULDERS OFF
FRAME 84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SUBJECT A
BEGIN PRESS
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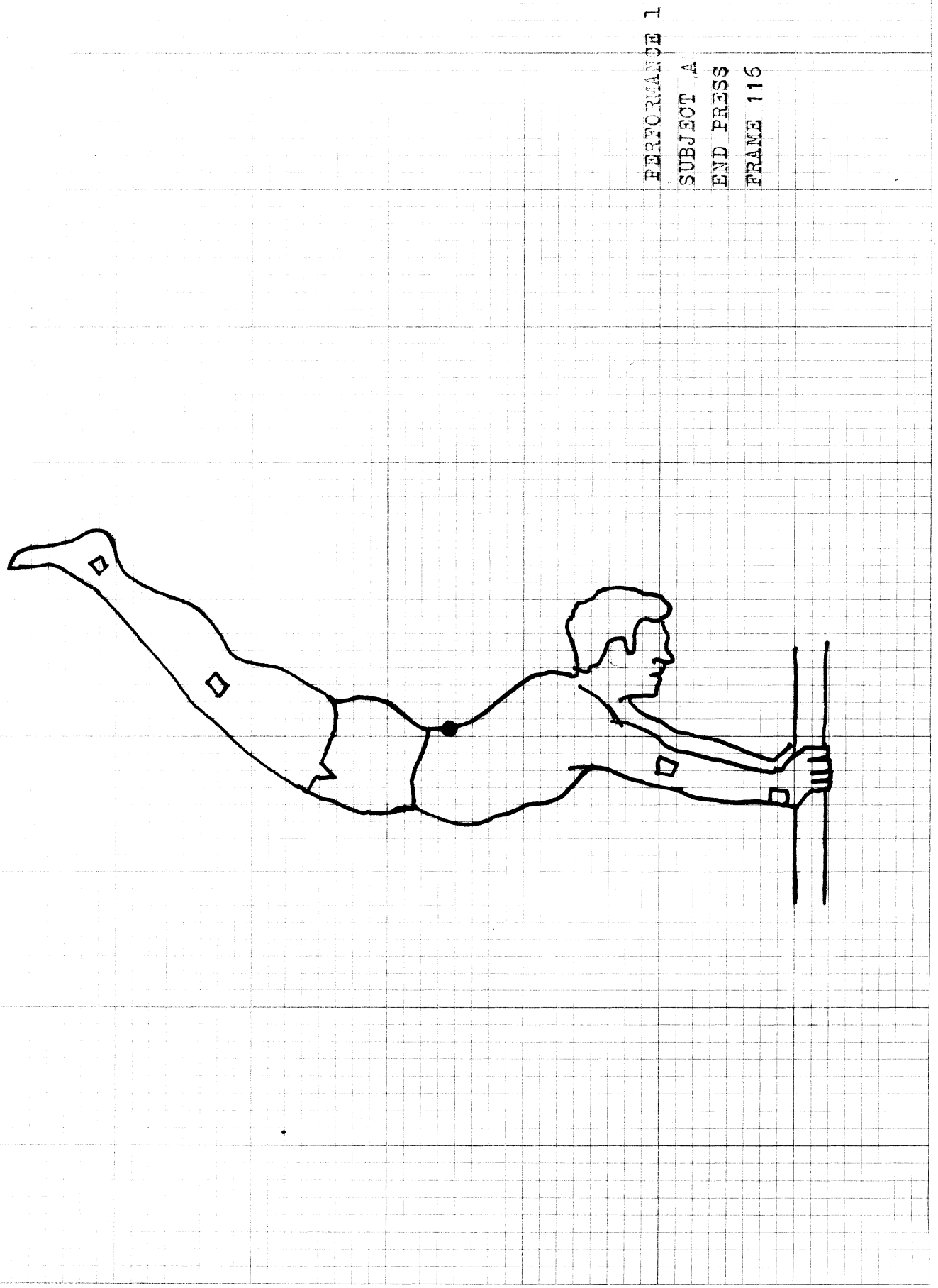
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END PRESS
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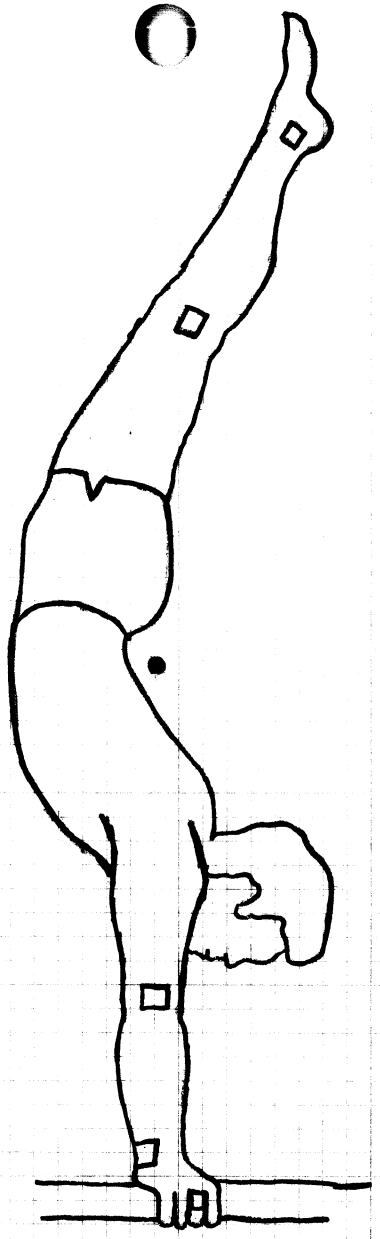

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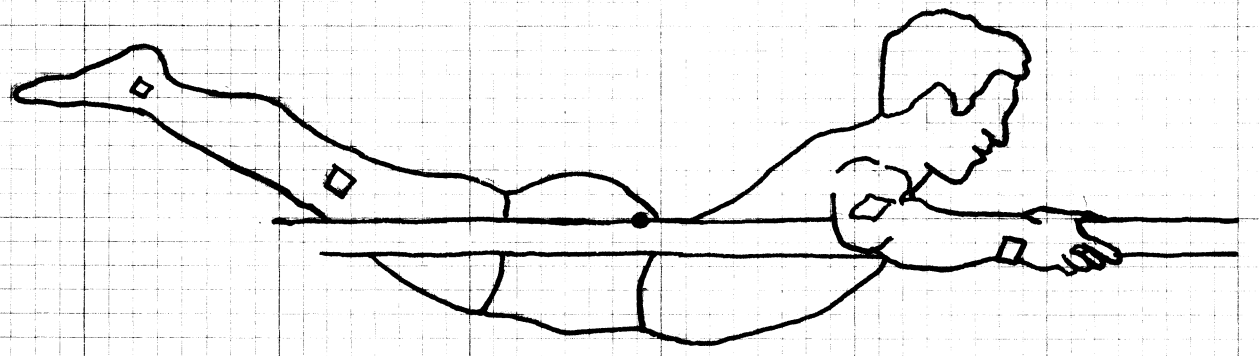

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SUBJECT A
SHOULDER TOUCH
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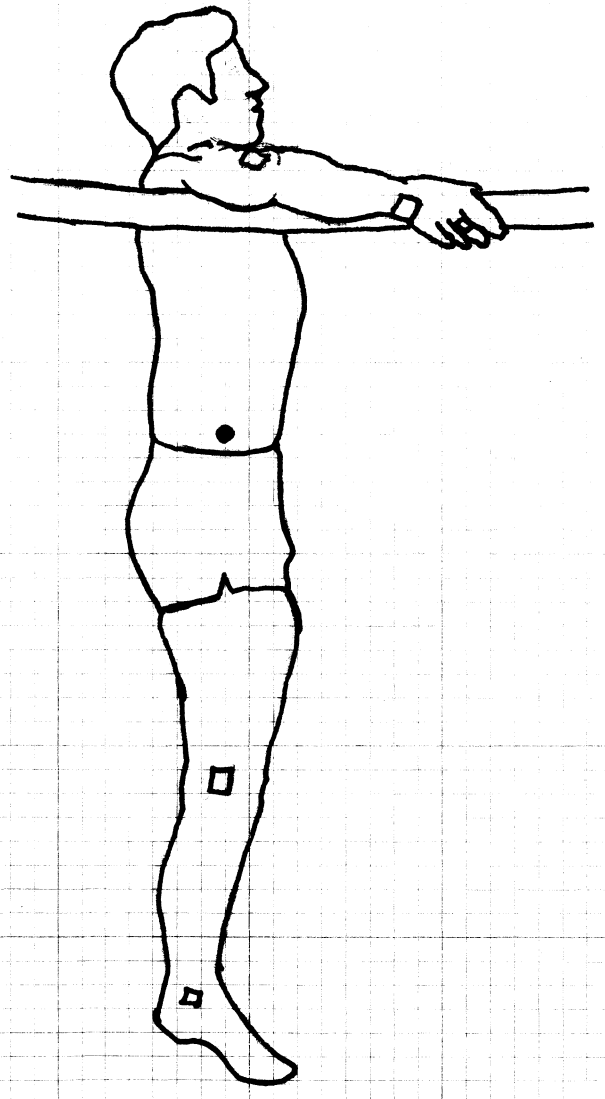

PERFORMANCE 2
SUBJECT A
LEGS VERTICAL
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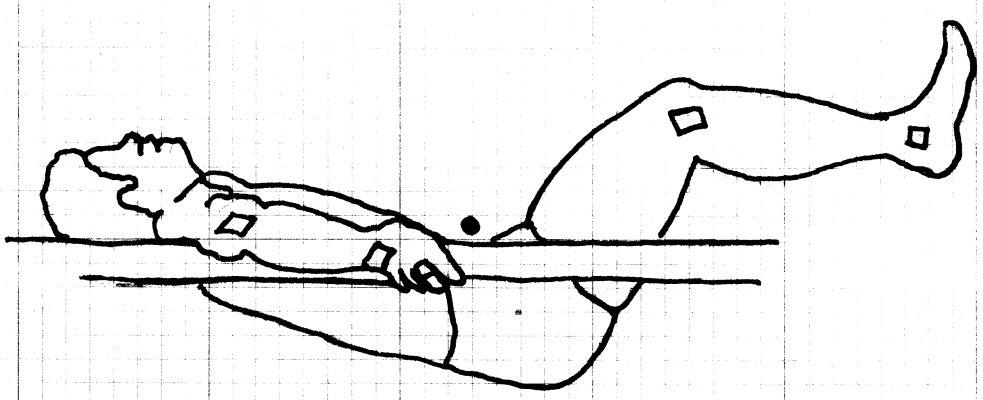

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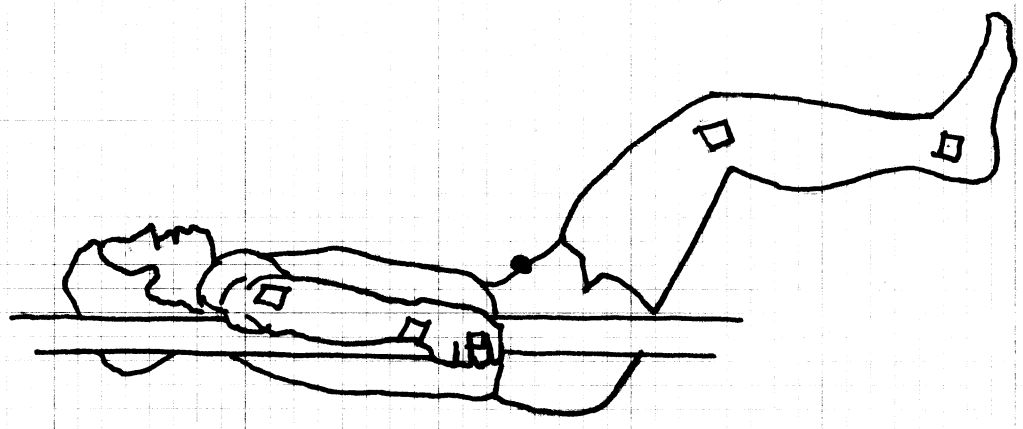

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SUBJECT A
BEGIN SHOOT
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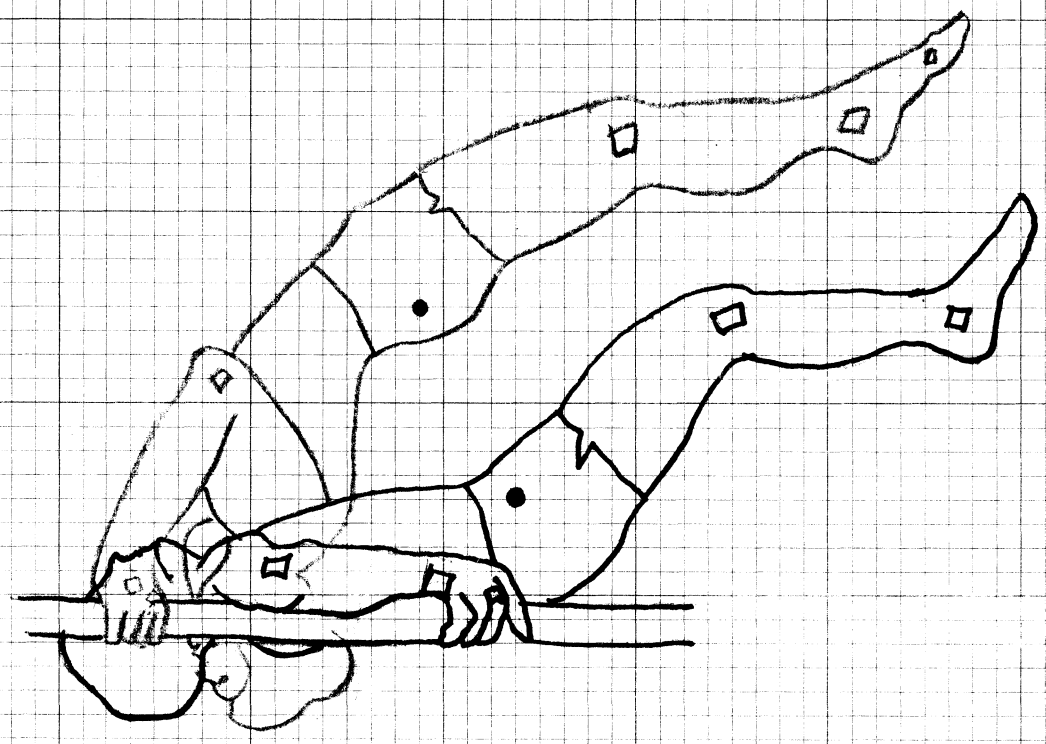
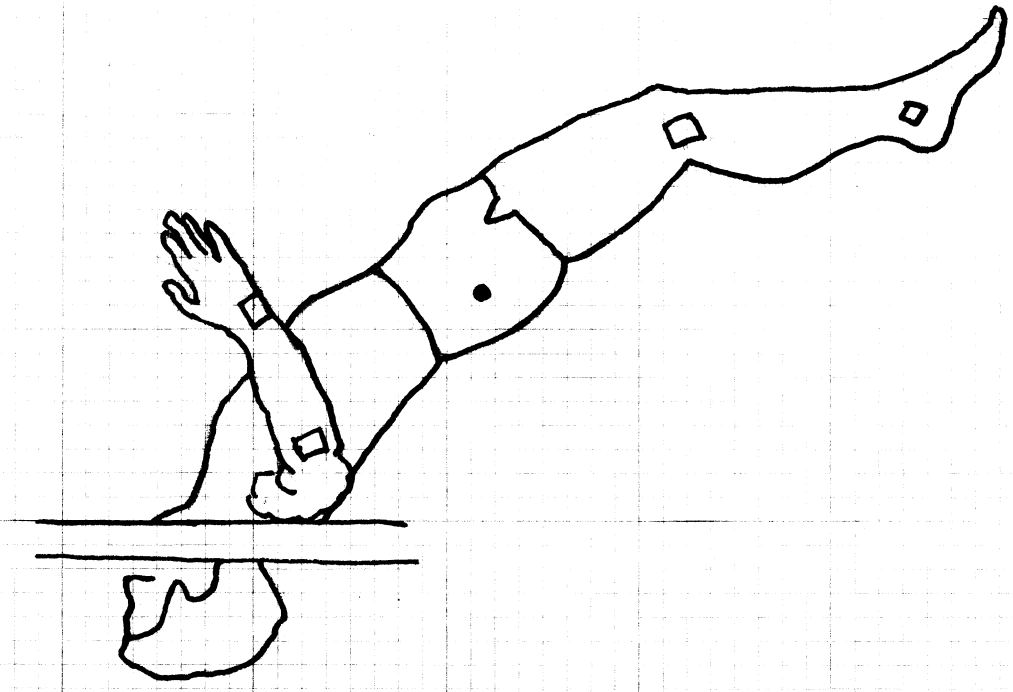


PERFORMANCE 2
SUBJECT A
REGRASP
FRAME 84

PERFORMANCE 2
SUBJECT A
RELEASE
FRAME 76



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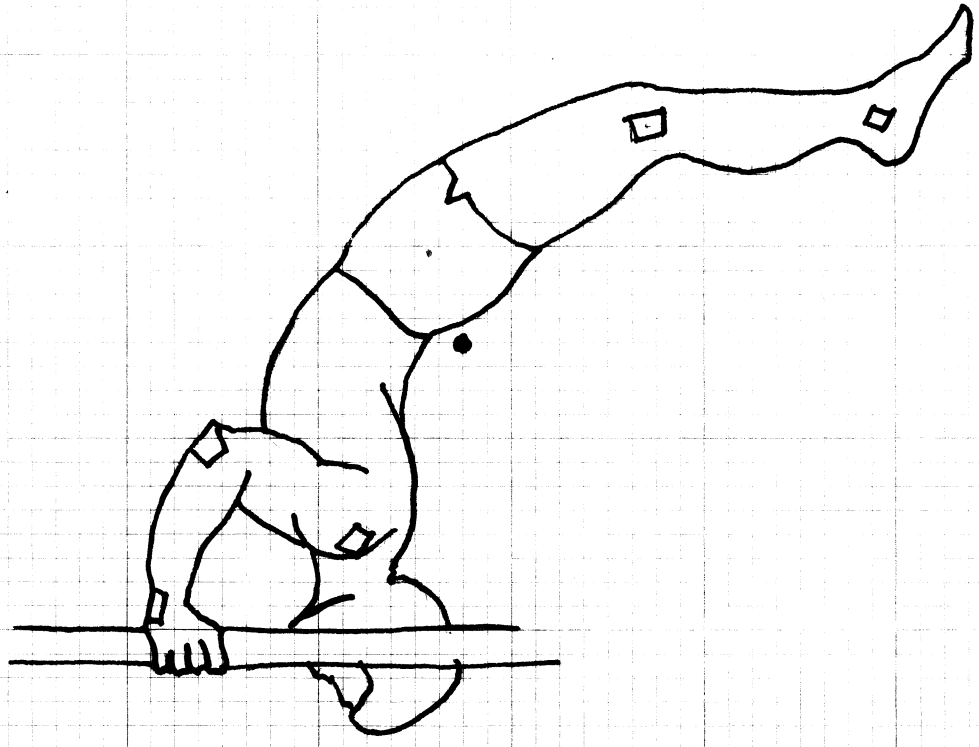
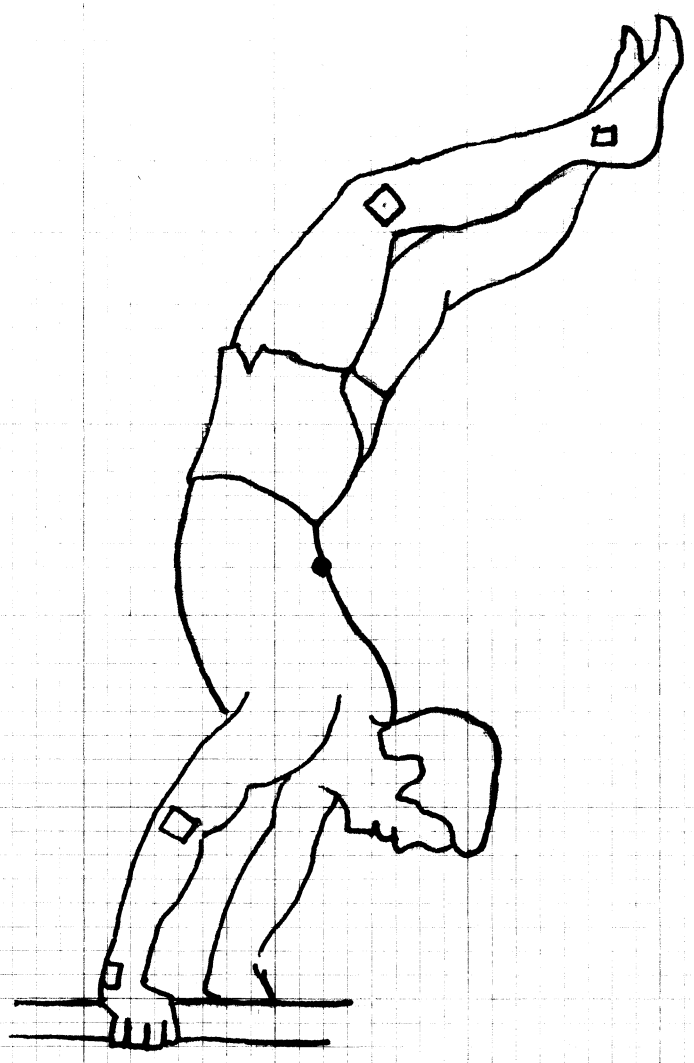
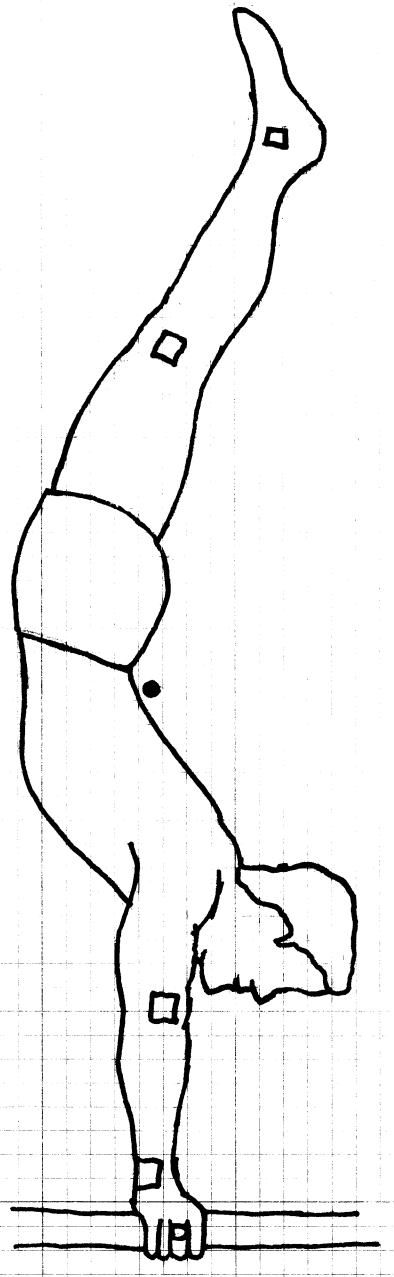
SUBJECT A.
SHOULDERS OFF
FRAME 80



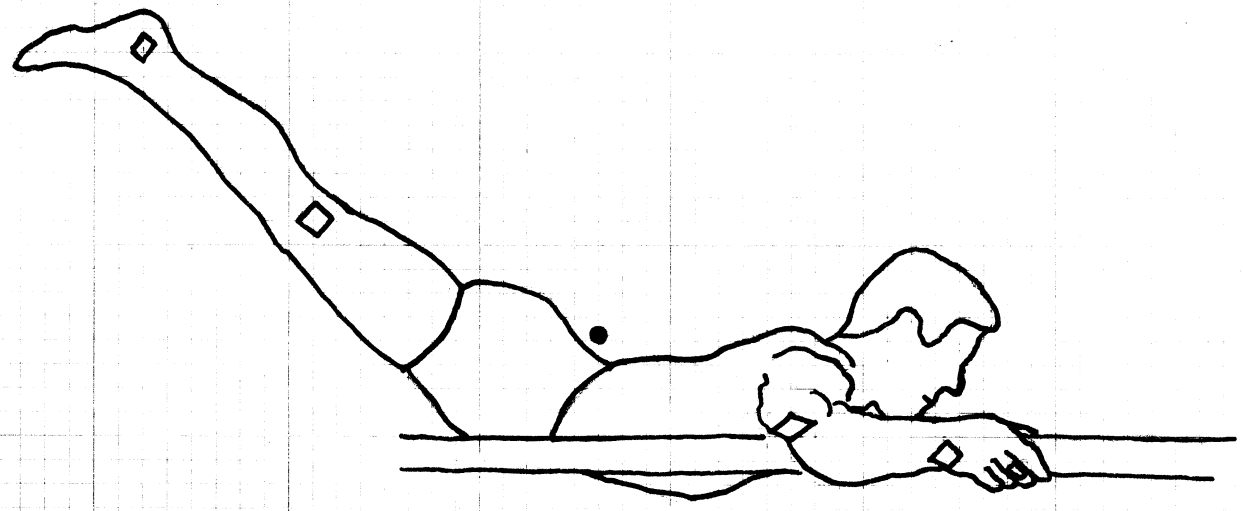
PERFORMANCE 2
SUBJECT A
BEGIN PRESS
FRAME 85



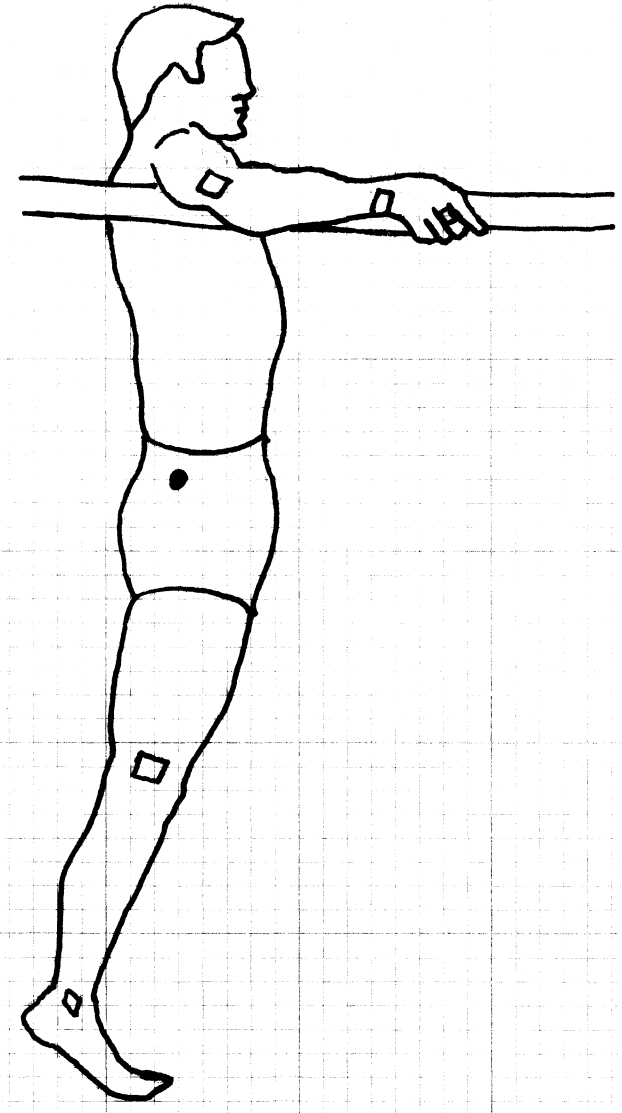
PERFORMANCE 2
SUBJECT A
END PRESS
FRAME 105



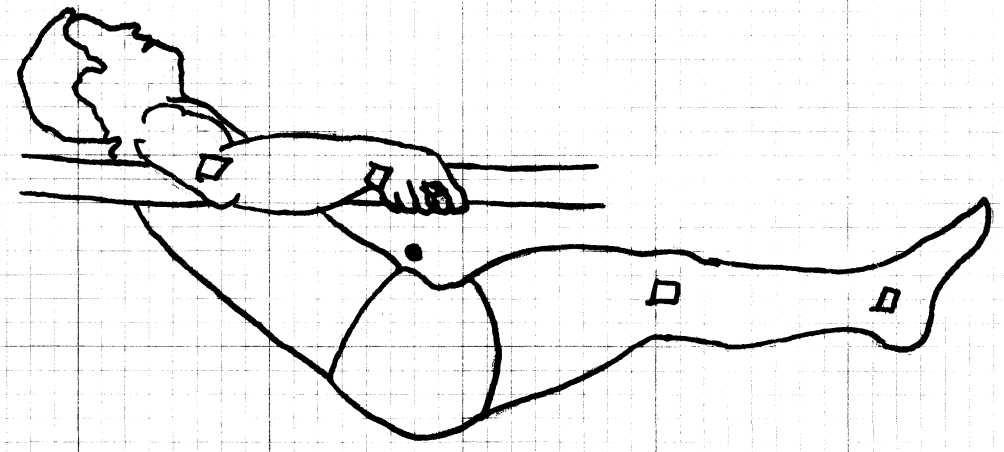
PERFORMANCE 3
SUBJECT B
START
FRAME 1



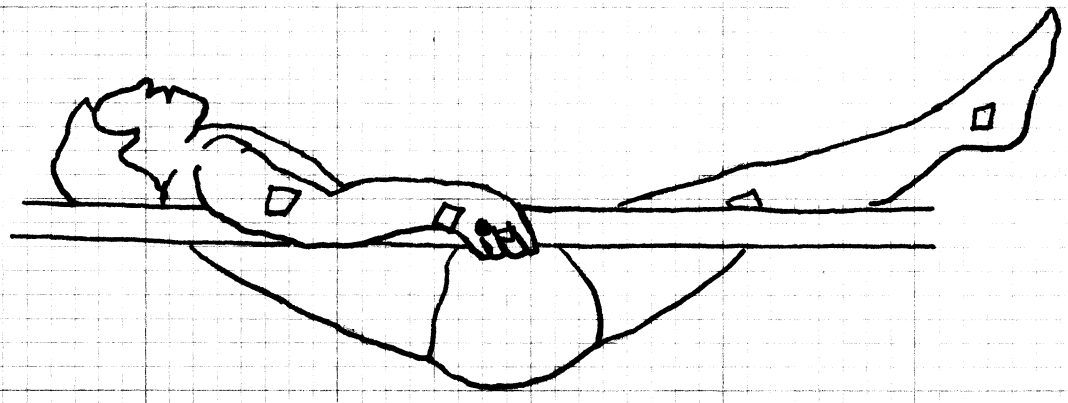
PERFORMANCE 3
SUBJECT „B
SHOULDER TOUCH
FRAME 59



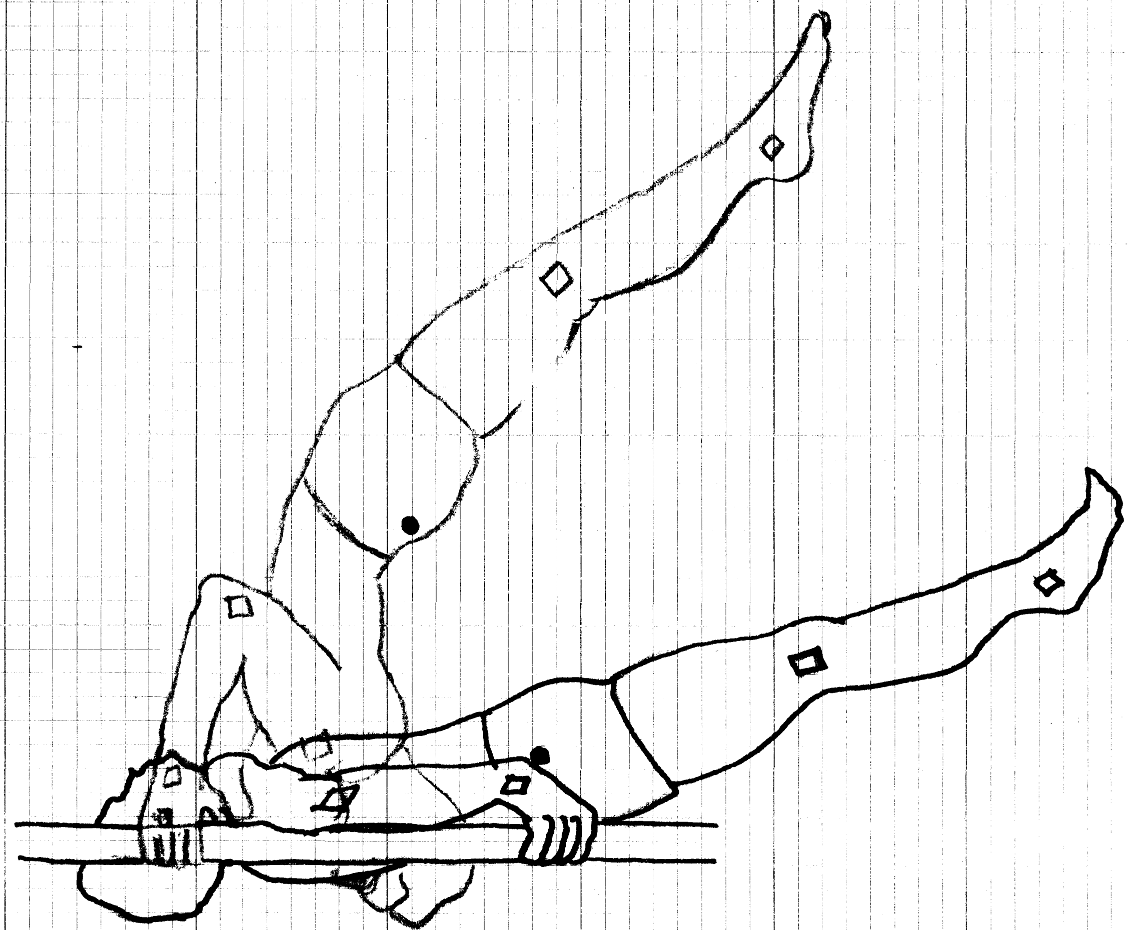
PERFORMANCE 3
SUBJECT B
LEGS VERTICAL
FRAME 74

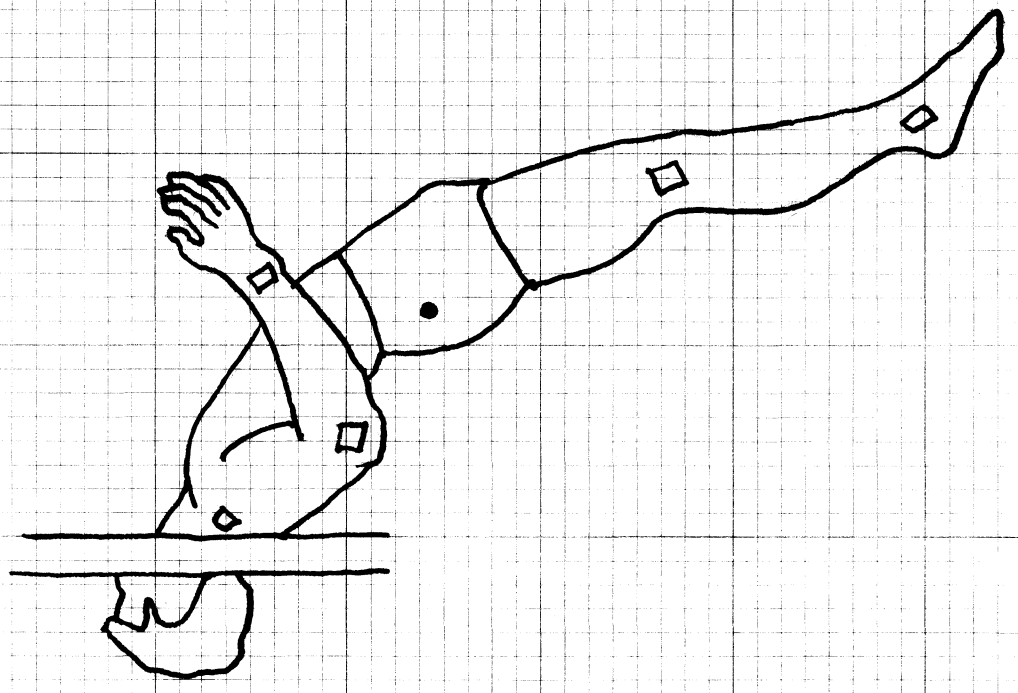


PERFORMANCE 3
SUBJECT B
DEEPEST PIKE
FRAME 84

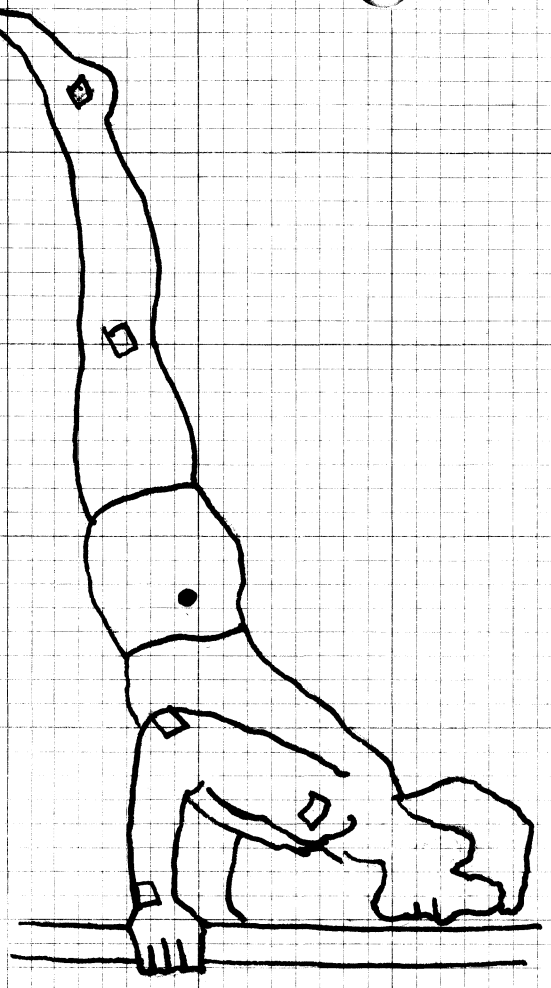


PERFORMANCE 3
SUBJECT B
BEGIN SHOOT
FRAME 86

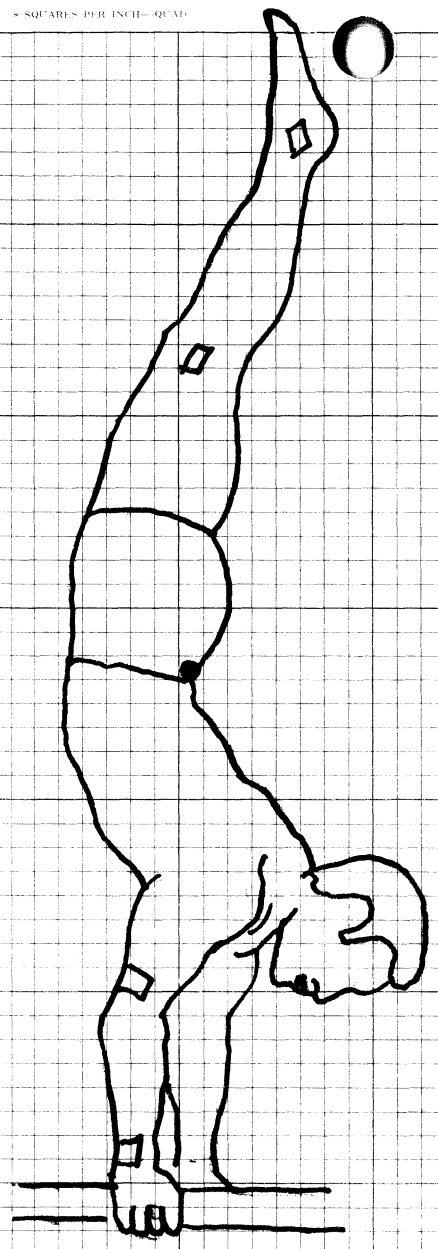

SUBJECT
REGRASP
FRAME 102
PERFORMANCE 3
SUBJECT B
RELEASE
FRAME 89



PERFORMANCE 3
SUBJECT B
SHOULDERS OFF
FRAME 95

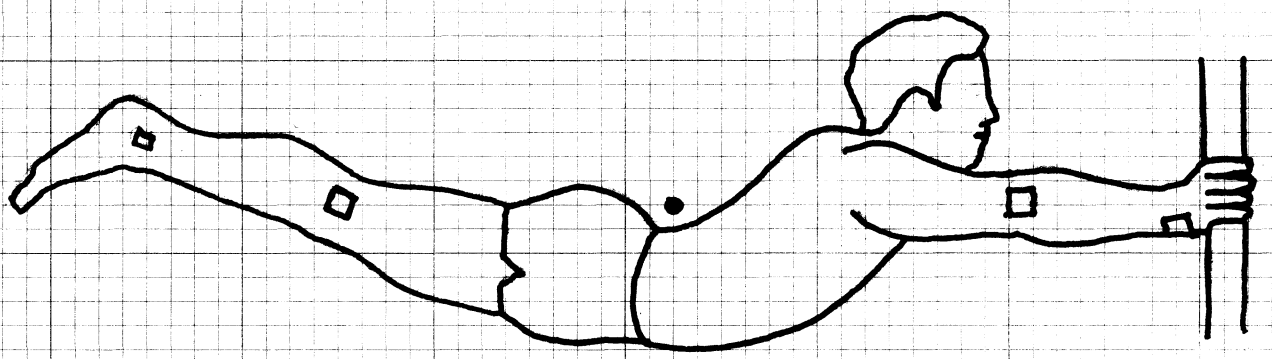


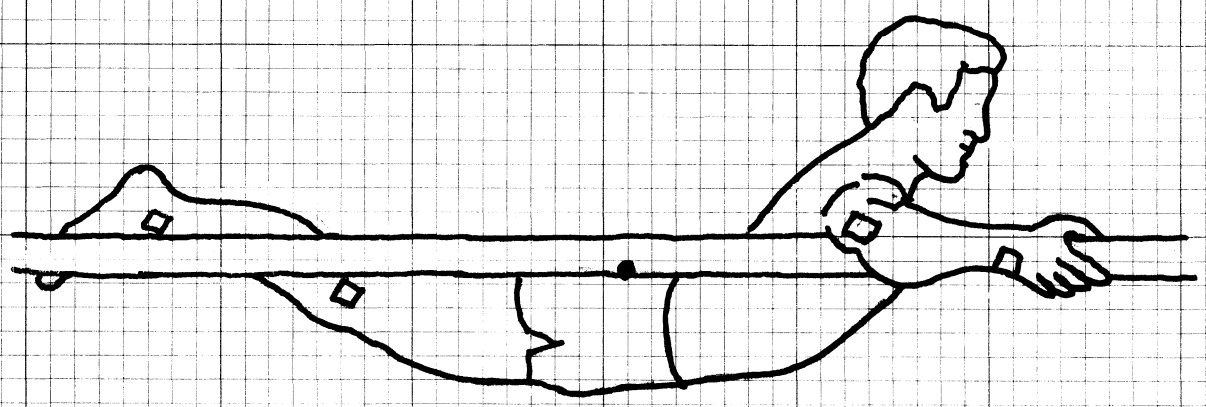
PERFORMANCE 3
SUBJECT B
BEGIN PRESS
FRAME 152



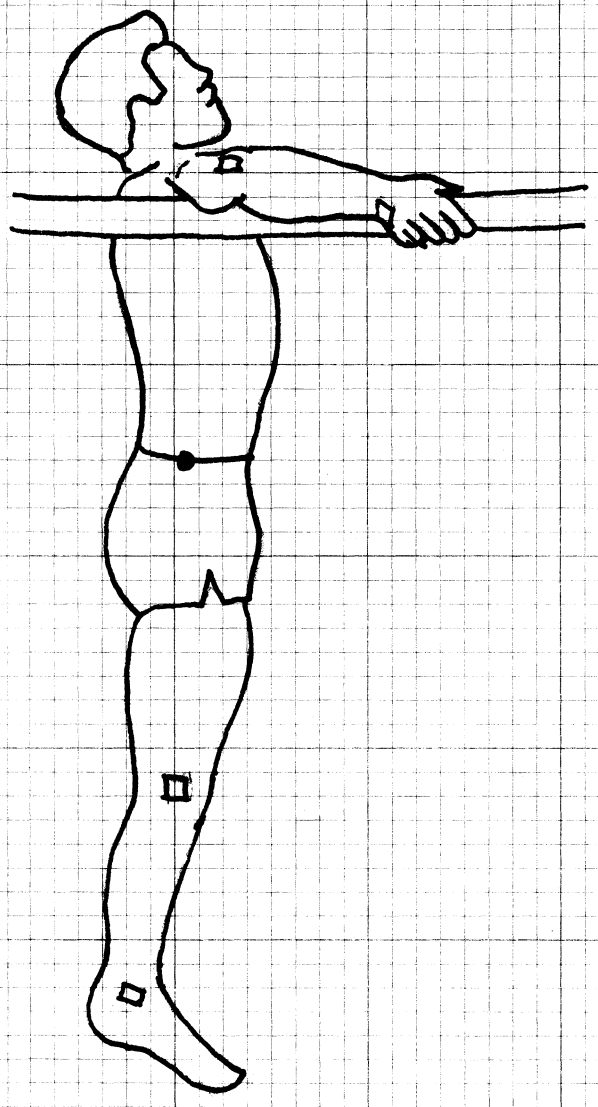
PERFORMANCE 3
SUBJECT ,B
END PRESS
FRAME 202

PERFORMANCE 4
SUBJECT C
START
FRAME 1

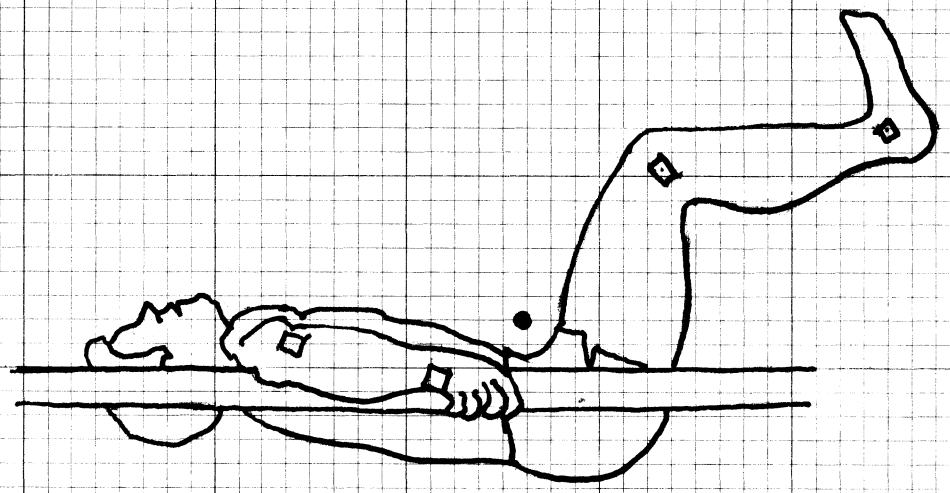




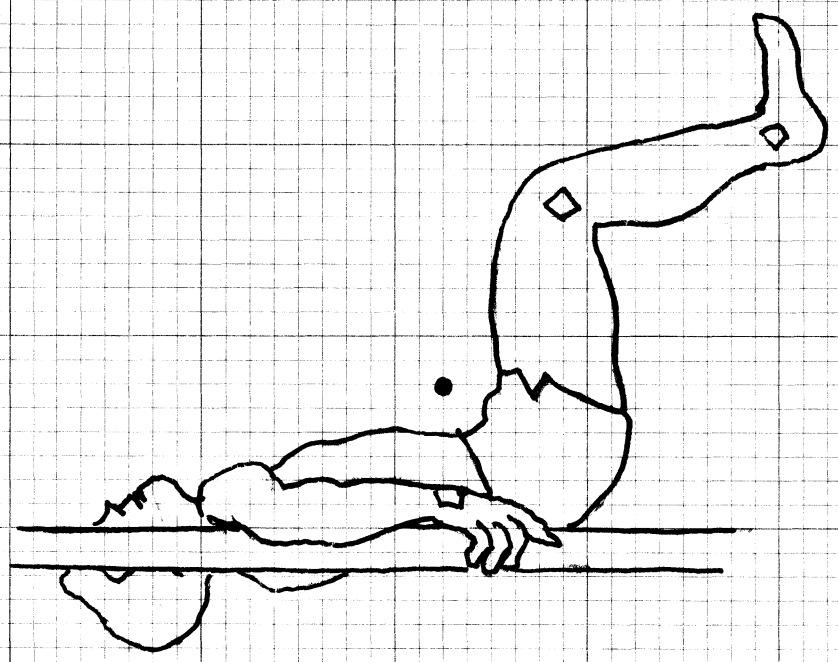
PERFORMANCE 4
SUBJECT C
SHOULDER TOUCH
FRAME 59



PERFORMANCE 4
SUBJECT 0
LEGS VERTICAL
FRAME 69



PERFORMANCE 4
SUBJECT .C
DEEPEST PIKE
FRAME 74

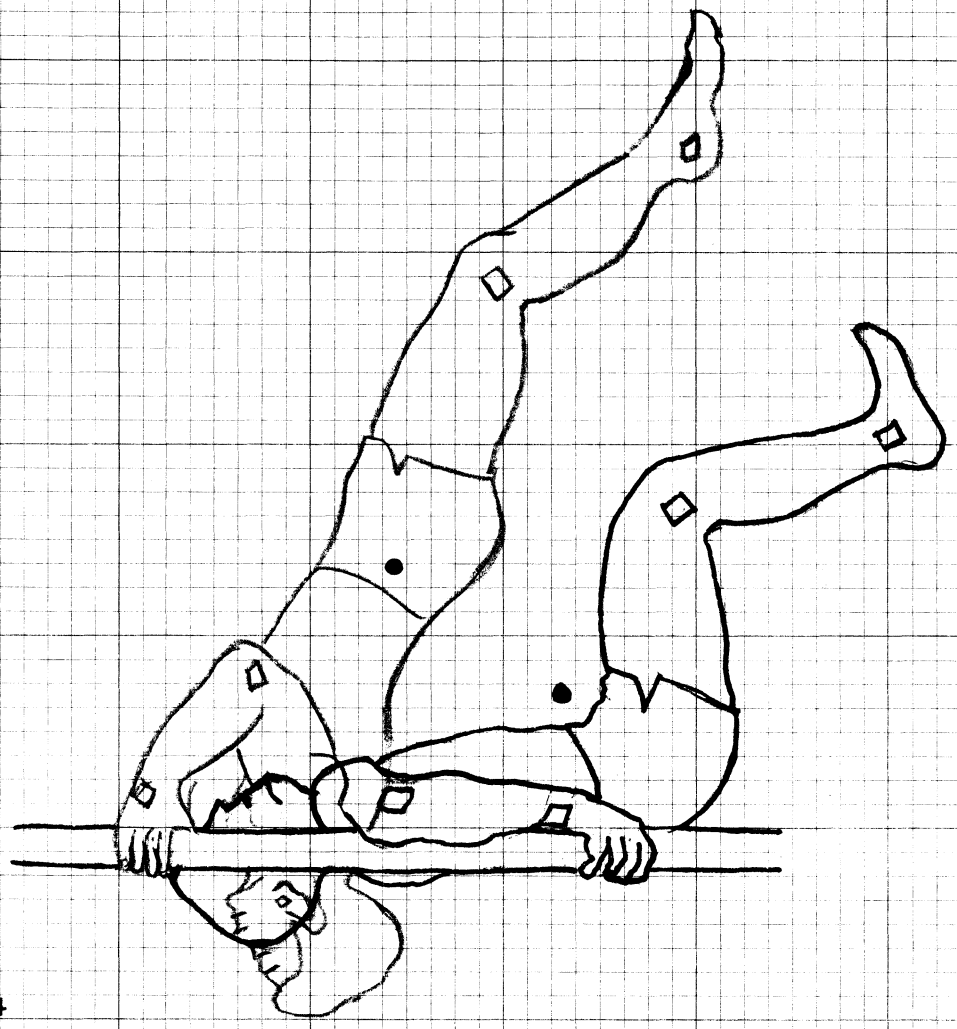


PERFORMANCE 4

SUBJECT C.

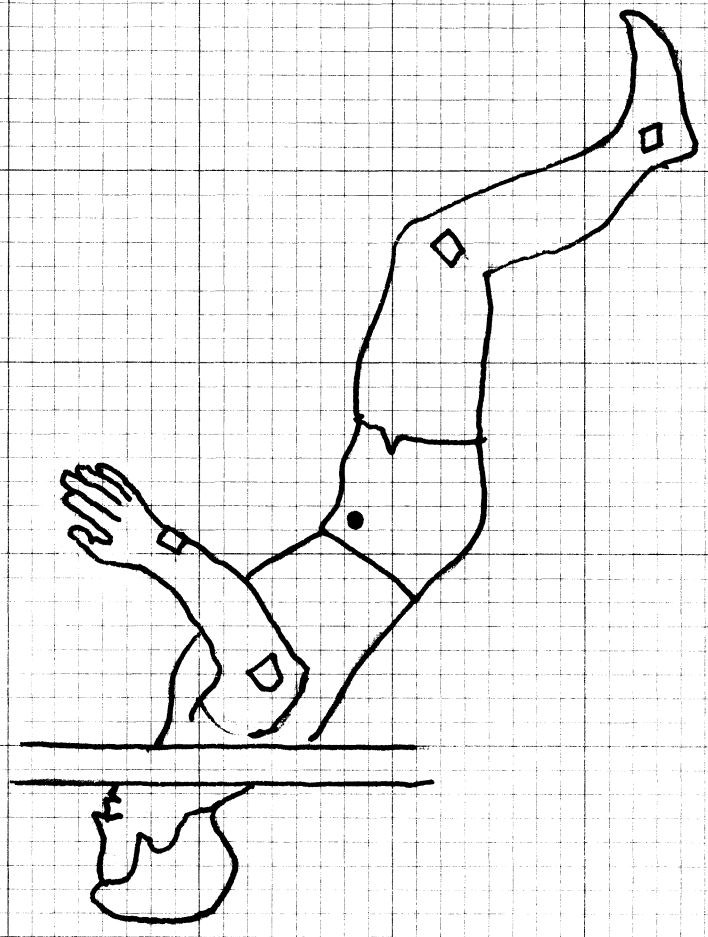
BEGIN SHOOT

FRAME 77

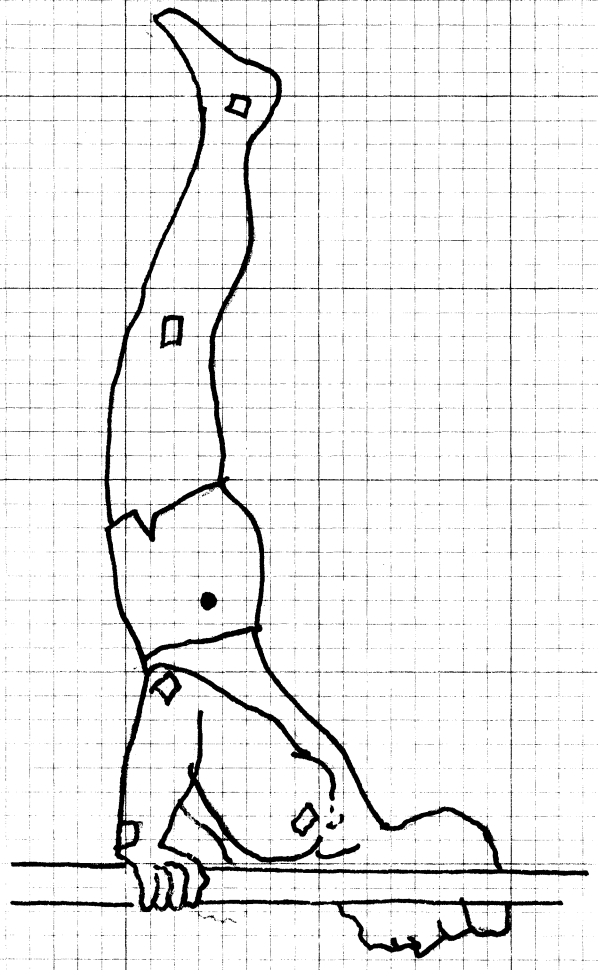


PERFORMANCE 4
SUBJECT C
REGRASP
FRAME 87

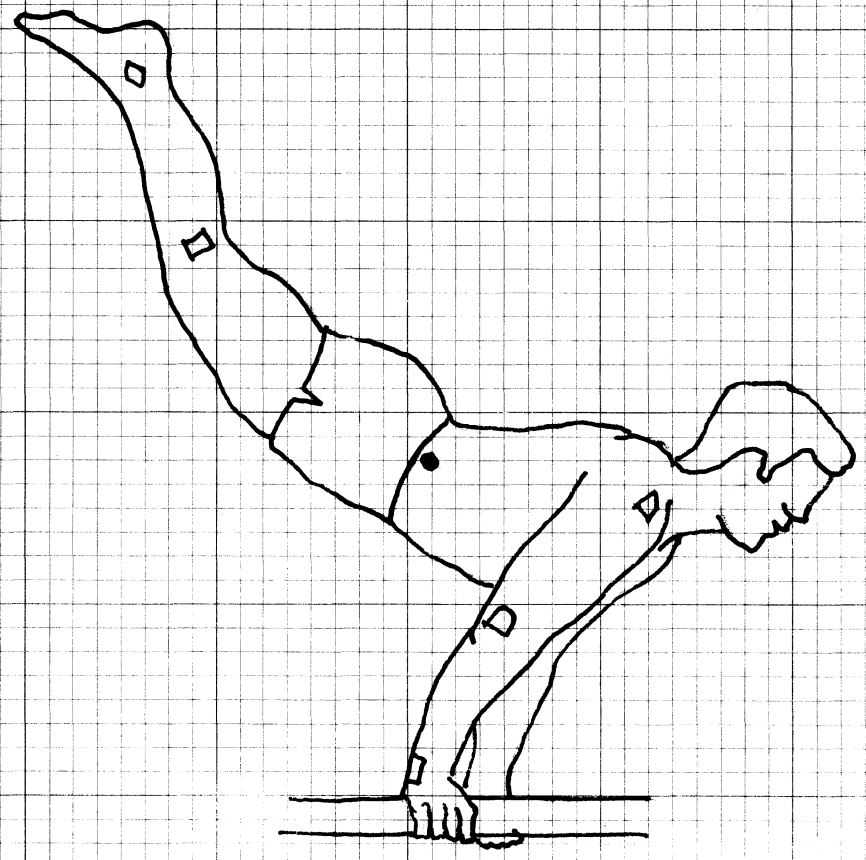
PERFORMANCE 4
SUBJECT C
RELEASE
FRAME 77



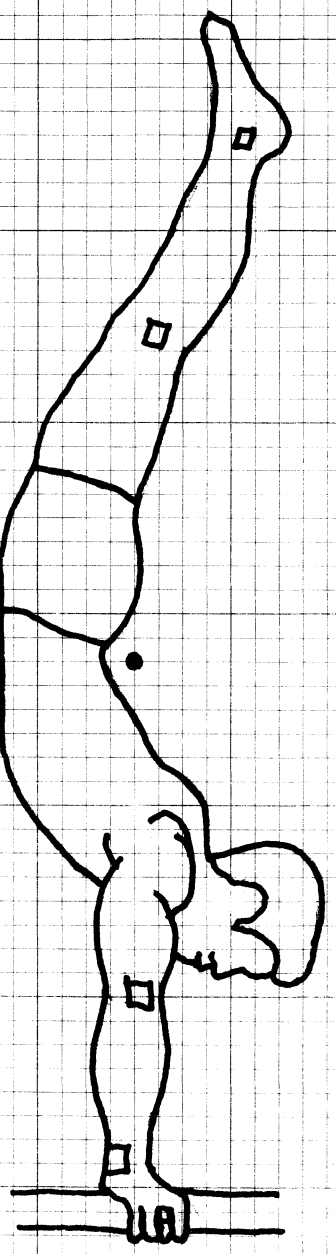
PERFORMANCE 4
SUBJECT .0
SHOULDERS OFF
FRAME 83



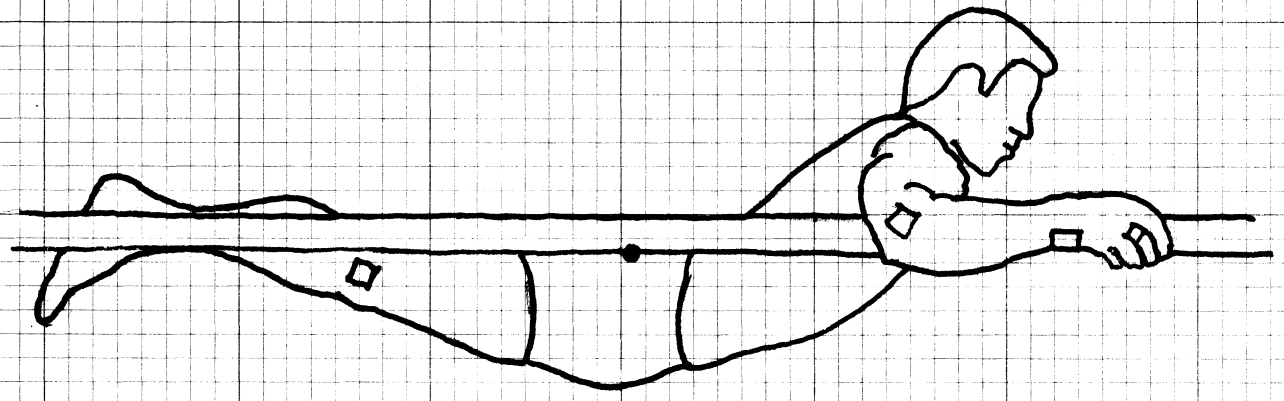
PERFORMANCE 4
SUBJECT C
BEGIN PRESS
FRAME 103



PERFORMANCE 4
SUBJECT C
END PRESS
FRAME 141



PERFORMANCE 5
SUBJECT B
START
FRAME 1



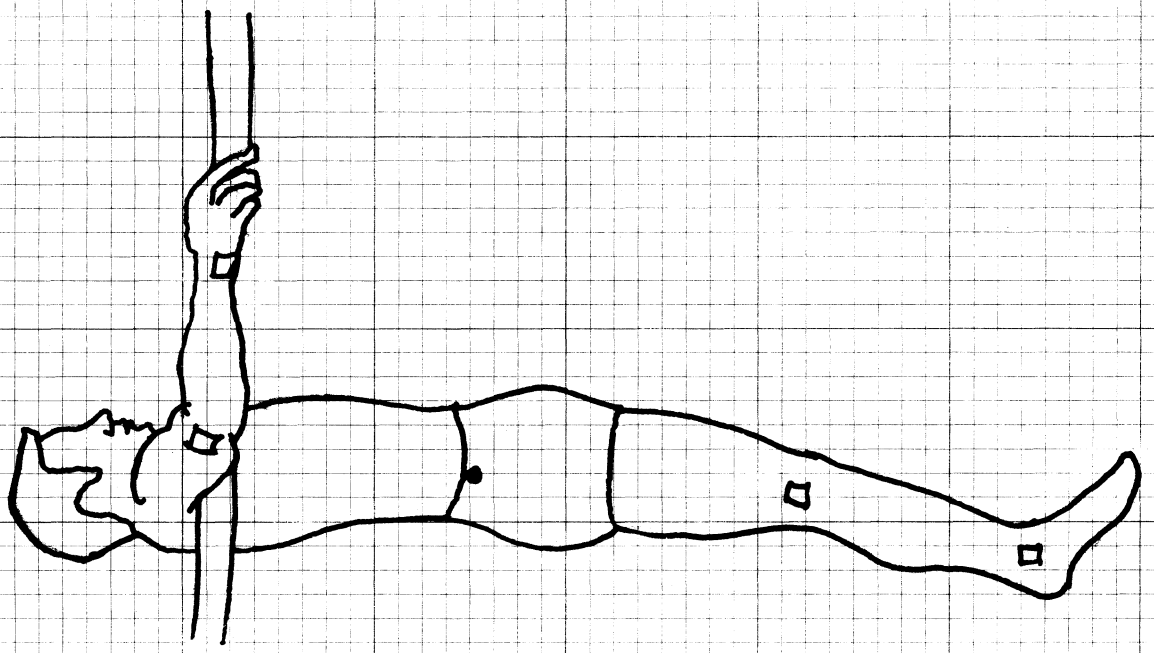
PERFORMANCE 5
SUBJECT ,B.
SHOULDER TOUCH
FRAME 61

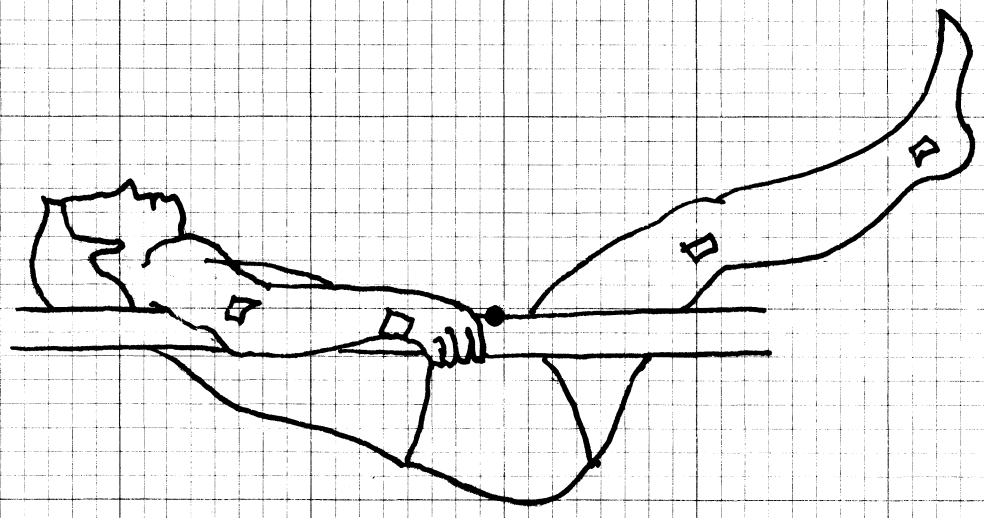
PERFORMANCE 5

SUBJECT B

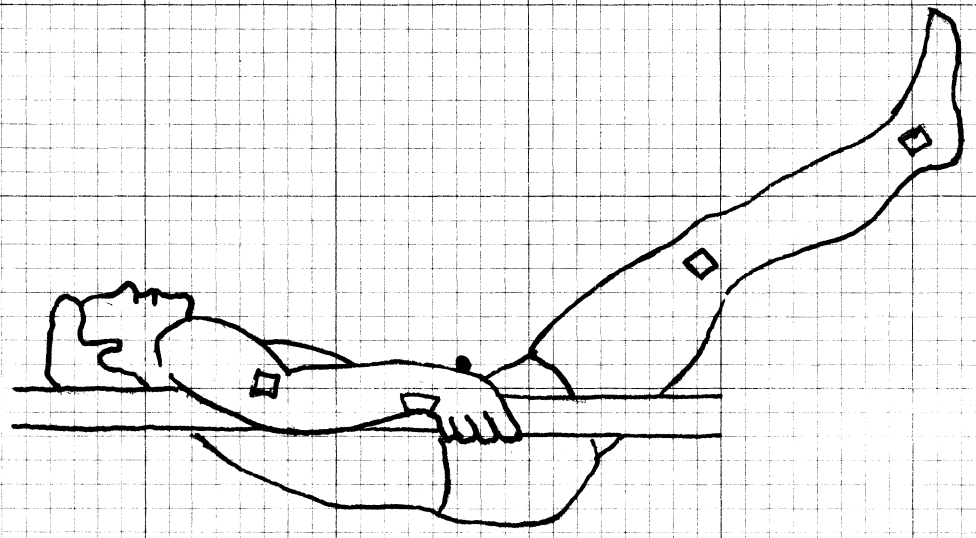
LEGS VERTICAL

FRAME 71





PERFORMANCE 5
SUBJECT B
DEEPEST PIKE
FRAME 84

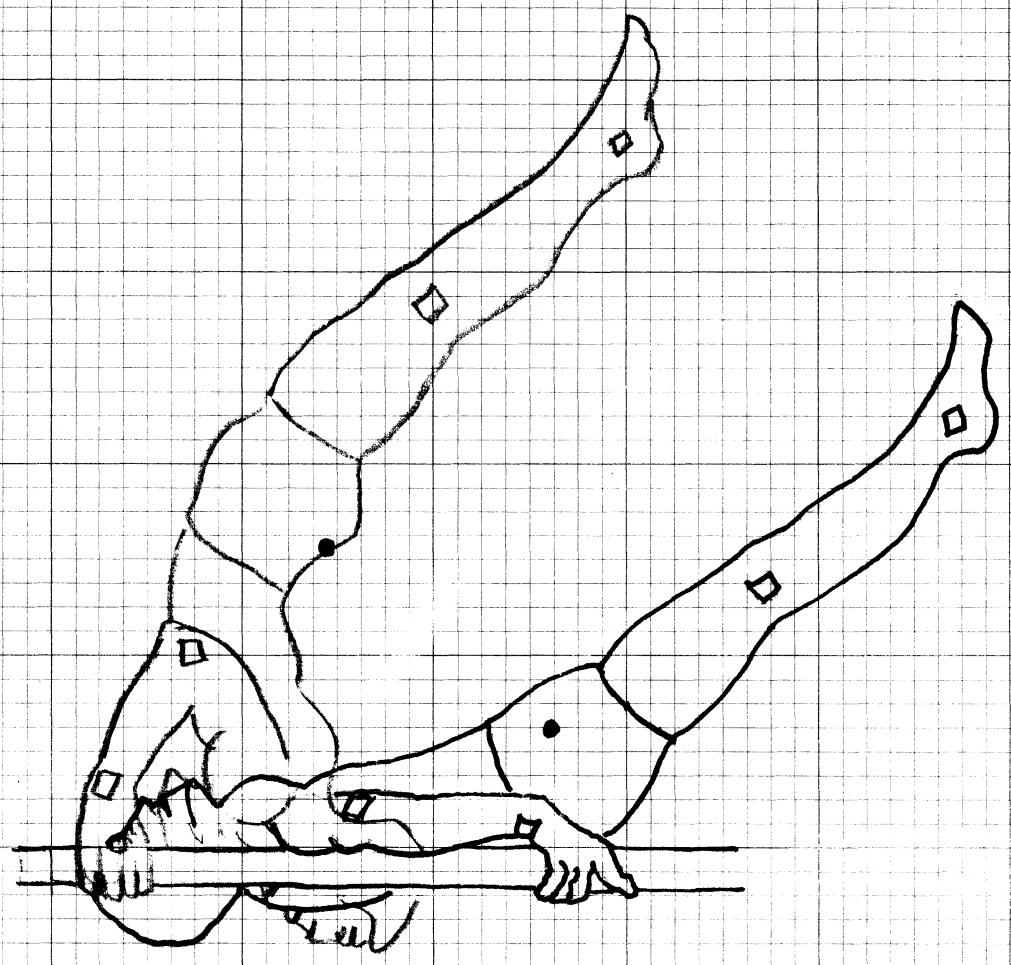


PERFORMANCE 5

SUBJECT B

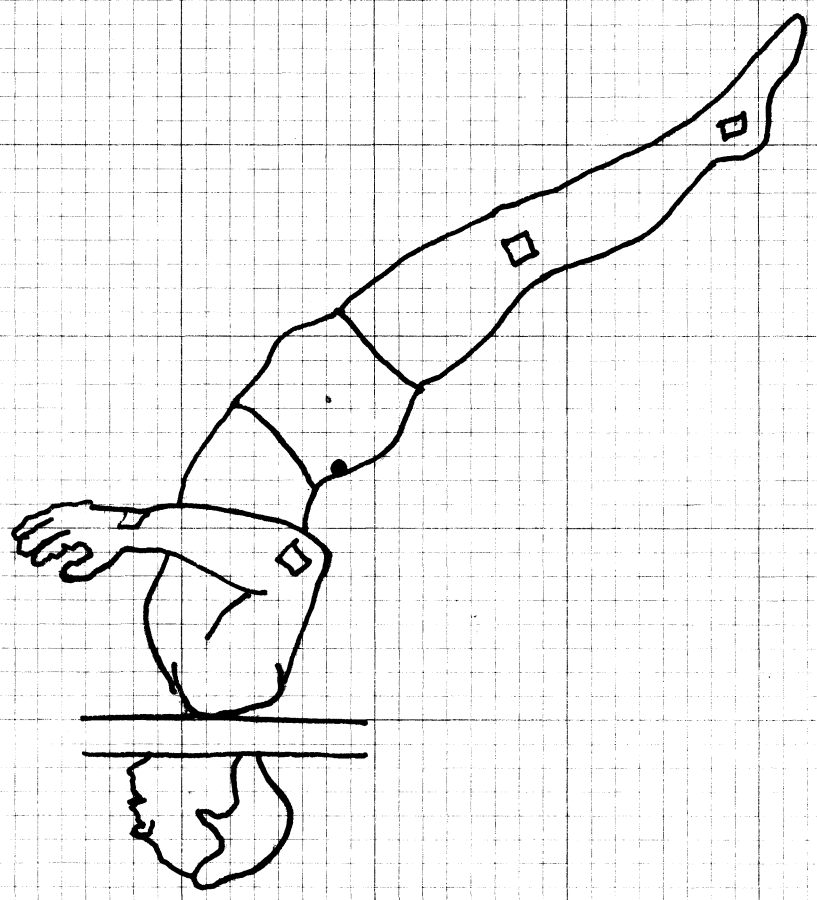
BEGIN SHOOT

FRAME 85

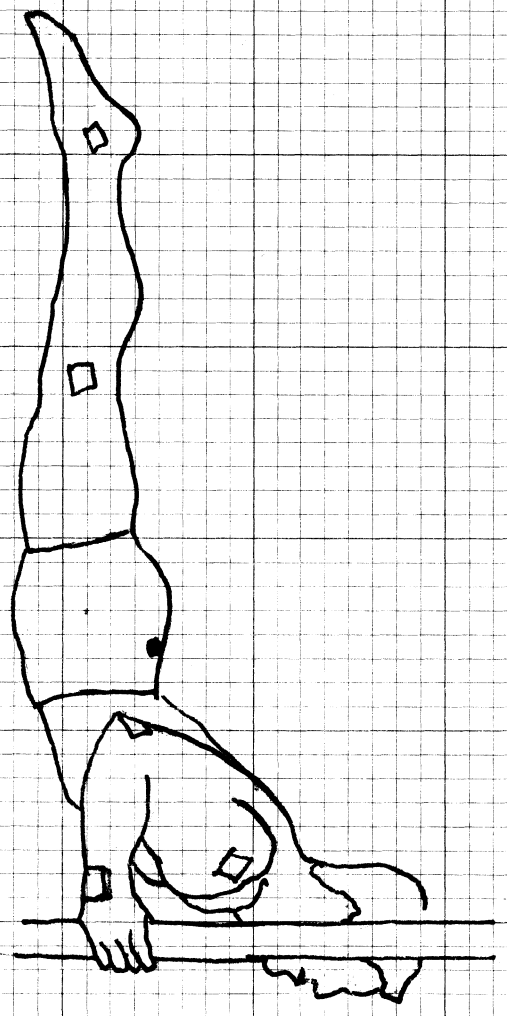


PERFORMANCE 5
SUBJECT B
REGRASP
FRAME 100

PERFORMANCE 5
SUBJECT B
RELEASE
FRAME 88



PERFORMANCE 5
SUBJECT B
SHOULDERS OFF
FRAME 95

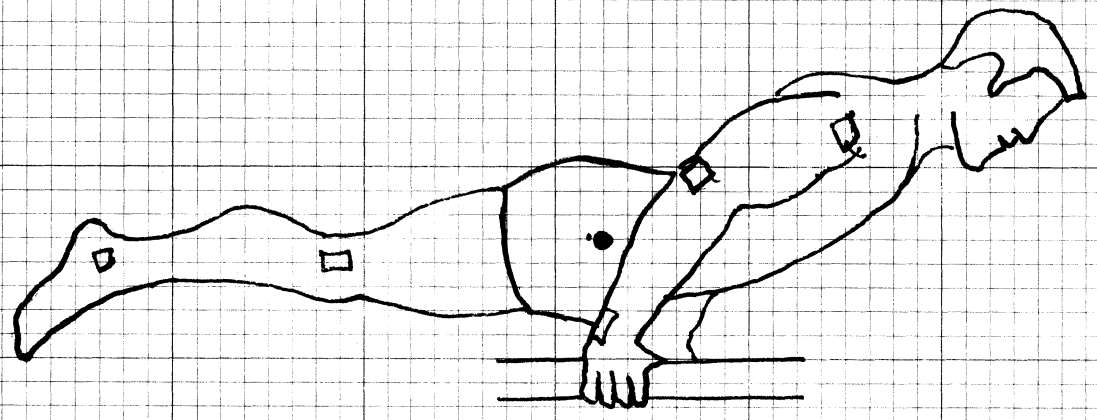


PERFORMANCE 5

SUBJECT B

BEGIN PRESS

FRAME 112



PERFORMANCE 5

SUBJECT B

END PRESS

FRAME 132

BIBLIOGRAPHY

Cureton, Thomas K. "Elementary Principles and Techniques of Cinematographic Analysis as Aids in Athletic Research," Research Quarterly, X, No. 2 (May, 1939), 3-24.

Glassow, Ruth (Chairman) and Hubbard, A.W. Research Methods Applied to Health, Physical Education, and Recreation. "Photographical and Cinematographical Research Methods." Washington, D.C.: American Association of Health, Physical Education and Recreation, 1949.

Hubbard, Alfred W. Research Methods in Health, Physical Education and Recreation. "Photography." Washington, D.C.: American Association of Health, Physical Education and Recreation, 1959.

_____. Research Methods Applied to Health, Physical Education and Recreation. "Research Methods in Mechanics of Sports and Physical Education Activities." Washington D.C.: American Association of Health, Physical Education, and Recreation, 1949.

Kunzle, G.C. Parallel Bars. London: Barrie and Rockliff, 1964.

Official Gymnastics Rules. New York: Amateur Athletic Union of the United States, 1962.

Sundby, Glenn. "Endo's Olympic Parallel Bar Routine," The Modern Gymnast, VII, No. 3 (March, 1965).

Yeager, Patrick. A Teacher's Guide for Men's Gymnastics. Georgia: Wide World Publications, 1963.